CALIFORNIA GEOLOGICAL SURVEY
FAULT EVALUATION REPORT FER 259

THE HOLLYWOOD, SANTA MONICA and NEWPORT-INGLEWOOD FAULTS in the Beverly Hills and Topanga 7.5' Quadrangles

Los Angeles County, California

by
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INTRODUCTION

The study area is located in the alluvial plain along the southern margin of the Santa Monica Mountains and features two very different fault zones, which interact with one another in a complex and not yet well understood manner (Figure 1). The Santa Monica and western Hollywood Faults are part of a complex zone of east-west-trending oblique, reverse and left-lateral faults, which bound the northern edge of the Los Angeles basin and separate the Transverse Ranges geomorphic province to the north from the Peninsular Ranges province to the south (Dolan *et al.*, 1997). Southeast of these fault zones and within the Los Angeles basin is the northern Newport-Inglewood Fault zone (NIFZ). This fault zone is chiefly a left-stepping series of right-lateral faults extending onshore from Newport Beach to the Cheviot Hills (Barrows, 1974; Bryant, 1985). The northernmost mapped surface traces of the NIFZ align with a feature informally known as the West Beverly Hills lineament (WBHL), which is a north-northwest trending series of relatively continuous east-facing escarpments that separate elevated older alluvium to the west and a gently sloping, younger alluvial plain to the east. It is unclear whether the WBHL is related to faulting or other surficial geologic processes; however, various tectonic models have been postulated to explain it (Dolan and Sieh, 1992; Dolan *et al.*, 1997).

Shallow subsurface data for these faults is relatively sparse given the area is heavily urbanized. Some data is available from several recent detailed geologic and geotechnical studies for commercial developments, public school improvements, and public works projects in the area surrounding the Century City region of Los Angeles and western Beverly Hills. Other geologic studies were performed for projects in western Los Angeles and West Hollywood. A few fault investigations for single-lot residential developments were completed along previously mapped traces of the NIFZ. All these reports contain data that provides valuable insight for evaluating the Hollywood, Santa Monica, and Newport-Inglewood Faults. The data suggests faulting occurred in Holocene time at a number of sites along the western portion of the Hollywood Fault, several strands of the Santa Monica Fault Zone, and two strands of the north Newport-Inglewood Fault Zone. Groundwater studies also provide support to infer that portions of these faults are active.

The Hollywood and Santa Monica Faults as defined in this report were previously evaluated under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act (Bryant and Hart, 2007) in 1978. For the initial evaluation, Smith (1978) reviewed the two subparallel faults along the Santa Monica Mountains range front relying chiefly on mapping and observations by Hill *et al.* (1978), without reviewing any aerial photographs or performing any field observations (Figure 3). Zoning was not recommended by Smith for any portion of the "Santa Monica Fault",

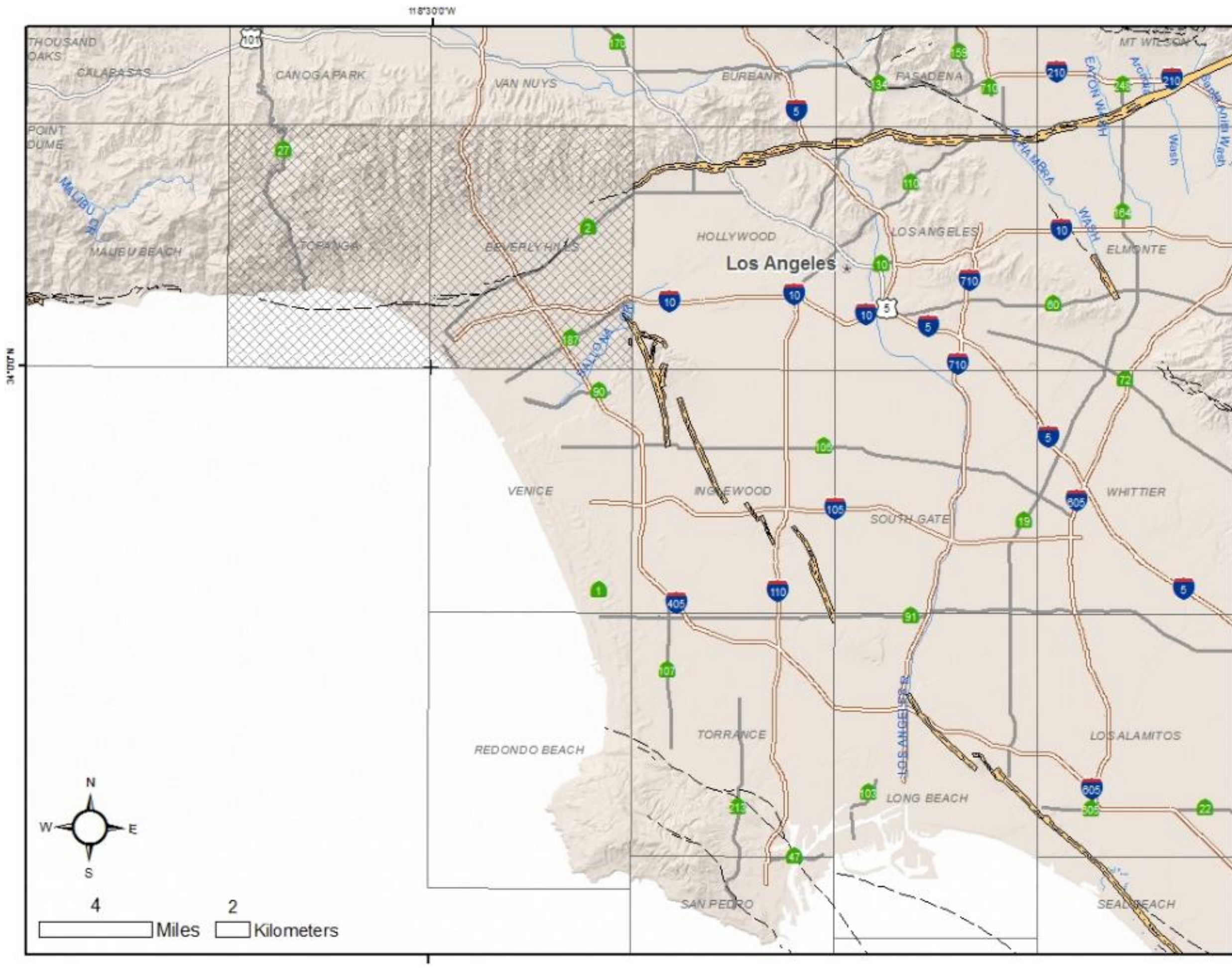

Figure 1 - Index map of the study area (cross-hatched); gray rectangles are USGS 7.5-minute quadrangle boundaries. Existing Alquist-Priolo Earthquake Fault Zones shown within orange-shaded boundaries; selected other faults are indicated by dark gray lines, which includes the Beverly Hills (right) and Topanga (left) 7.5-minute quadrangles.

as it was called in that report, because the fault "is very poorly defined and…[t]here is no specific evidence to indicate that there has been Holocene activity along the fault." Subsequent geologic and geotechnical investigations, paleoseismic studies, and geomorphologic interpretations reported by Dolan *et al.* (1997, 2000b), and other published and unpublished research, prompted CGS to re-evaluate the evidence for Holocene displacement along traces of the western Hollywood Fault. The portion of the Hollywood Fault within the Hollywood quadrangle was recently evaluated and included in an Alquist-Priolo Earthquake Fault Zone based on the review by Hernandez and Treiman (2014). The Santa Monica Fault, as defined in this report, was not previously evaluated.

An Alquist-Priolo Earthquake Fault Zone (APEFZ) was initially established for the NIFZ in 1976 based primarily on mapping by Poland *et al*. (1959). The northern NIFZ and zone within the Beverly Hills 7.5-minute quadrangle was later re-evaluated and reconfigured by Bryant (1985), which incorporated thorough aerial photograph review, geomorphic evaluation, and data from individual fault investigations for sites in the initial APEFZ.

The purpose of this report is to assess the location and activity of fault strands associated with the Hollywood, Santa Monica, Newport-Inglewood Fault Zones, as well as evaluate possible

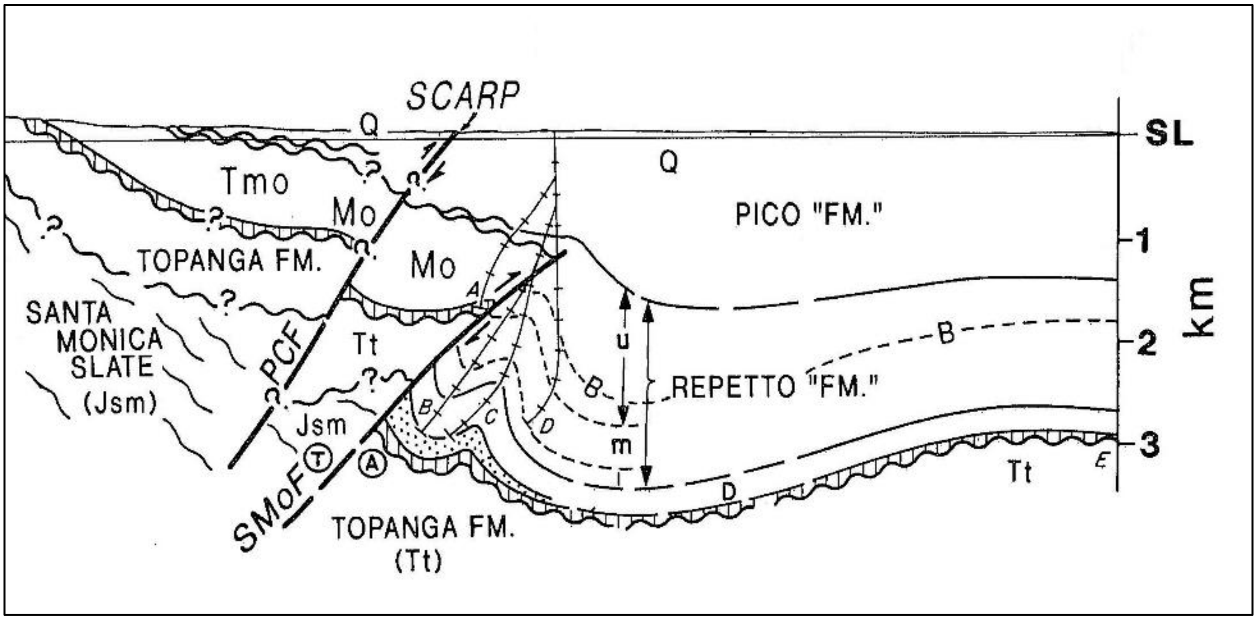

Figure 2 – Geologic cross section showing geometry and nomenclature of the Santa Monica Fault Zone. The basal low-angle blind thrust fault is referred to as the "Santa Monica Fault" (SmoF) and the high-angle hanging wall fault is named the "Potrero Canyon Fault" (PCF). Tmo/Mo = Modelo Formation; Tt = Topanga Formation (modified from cross section I-I' in Wright, 1991)

faulting associated with the West Beverly Hills lineament within the Beverly Hills and Topanga 7½-minute quadrangles. Those faults determined to be sufficiently active (Holocene) and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Earthquake Fault Zoning (AP) Act of 1972 (Bryant and Hart, 2007).

GEOLOGIC SETTING

The Santa Monica-Hollywood Fault system serves as the southern boundary of the western Transverse Ranges in the western Los Angeles Basin. The Hollywood Fault is located at the southern boundary of the Santa Monica Mountains, where Jurassic Santa Monica Slate and Cretaceous granitic rocks are unconformably overlain by Cretaceous Tuna Canyon Formation (turbidites) and Middle Miocene Modelo Formation marine siltstones and shales (Yerkes, 1997). Moving westward, it appears the Hollywood fault steps approximately 2-3 km south, away from the mountain front, to the Santa Monica Fault. Here the Pleistocene alluvial fan deposits emanating from the southern margin of the mountains are highly dissected and the Holocene alluvial fan deposits are typically found south of a prominent geomorphic scarp.

Overall, the study area is highly developed and urbanized. Continuing development mainly consists of in-fill projects and redevelopment of existing sites. To facilitate discussion of the various research and site-specific studies for these three major fault zones, the summary of the available data is grouped by fault, beginning with the Santa Monica Fault in the west, then the Hollywood Fault, and lastly the Newport-Inglewood Fault Zone to the south. Because of the postulated connection with the northern NIFZ, the West Beverly Hills Lineament will be discussed in the NIFZ section.

SUMMARY OF AVAILABLE DATA FOR THE SANTA MONICA FAULT

LITERATURE REVIEW

The major fault system along the southern boundary of the Transverse Ranges was recognized early on as a result of many geologic studies seeking to identify potential oil reservoirs in the Los Angeles basin. McLaughlin and Waring (1914), summarizing the dominant structural features of this region, identified a fault "which runs along the southern face of the Santa Monica Mountains" they termed the Santa Monica Fault. Subsequent geologic surface mapping by workers such as Hoots (1931) and Castle (1960b) did not identify a through-going surface fault south of the Santa Monica Mountains, with the exception of a short unnamed fault segment mapped in the Pacific Palisades area. Yerkes *et al*. (1965) mapped the southern Transverse Ranges boundary fault zone as two subparallel faults trending along the southern edge of the Santa Monica Mountains (Figure 3). These faults extend onshore from Pacific Palisades and continue through Santa Monica and Beverly Hills to Hollywood, where they merge into a single fault strand. These subparallel faults were referred to by Yerkes *et al*. (1965) as the "Santa Monica fault zone". From here the fault continues east to merge with the Raymond Fault ("Raymond Hill fault" in Figure 3), east of the Los Angeles River. It was not until the late 1970s that detailed studies of this major surface fault were conducted by Hill (1979) and Hill *et al*. (1978, 1979b). These workers mapped the fault zone based on subsurface oil and groundwater well data. Additionally, they evaluated the fault exposures at Potrero Canyon northwest of Santa Monica, and mapped in detail the locations of several geomorphic features, such as the series of well-defined discontinuous scarps in the Pleistocene marine terrace deposits at Pacific Palisades and the alluvial fans emanating from the Santa Monica Mountains. Hill *et al*. (1978) adopted the name "Santa Monica Fault", used earlier by Yerkes *et al*. (1965), for the entire southern boundary fault zone west of Los Angeles. Wright (1991), using a wealth of data collected from extensive urban oil exploration up through the 1960s, discovered the Santa Monica fault zone consists of a north-dipping blind reverse fault and a subparallel fault in the hanging wall that reaches the surface. Wright named the blind fault the "Santa Monica Fault". The subparallel surface fault, which is the fault associated with the noted surficial scarps and shallow groundwater barriers, he named the "Potrero Canyon Fault" (Figure 2). This report uses "Santa Monica Fault" to refer to the surface fault under evaluation as this name is more commonly used in regional mapping of this area of the Los Angeles Basin. More recent geomorphic interpretations by Dolan and Sieh (1992), Dolan *et al*. (2000a), Kenney Geoscience (2011, 2012, 2013, 2016), as well as site-specific subsurface data by private consulting geologists (discussed later in this report), provide a more detailed view of the fault location and geometry. The surface traces of the Santa Monica Fault Zone mapped by various workers and the locations of other notable geologic studies along the fault are depicted on Plate 1.

As part of the Western Transverse Ranges southern boundary fault zone, the Santa Monica Fault exhibits a strong component of reverse motion evidenced by the uplift of the Santa Monica Mountains, the roughly continuous south-facing scarp observed at the surface, and limited subsurface investigations across the fault (Dolan and Sieh, 1992; Dolan *et al*., 2000a). Additionally, an appreciable amount of left-lateral slip is inferred from the left-stepping *en echelon* pattern of the fault traces from east to west and measured offsets of subsurface geologic marker units (Yerkes *et al.*, 1965; Wright, 1991). Subsurface investigation by Dolan *et al*. (2000a) also supports a component of left-lateral motion. Dolan and Pratt (1997) and Dolan *et al*. (2000a) calculated minimum dip-slip only rates of approximately 0.5 to 0.6 mm/year, while Cooke and Marshall (2006) report a net slip rate of approximately 1.0 mm/year for the Santa Monica Fault based on mechanical models of the faults in the Los Angeles Basin.

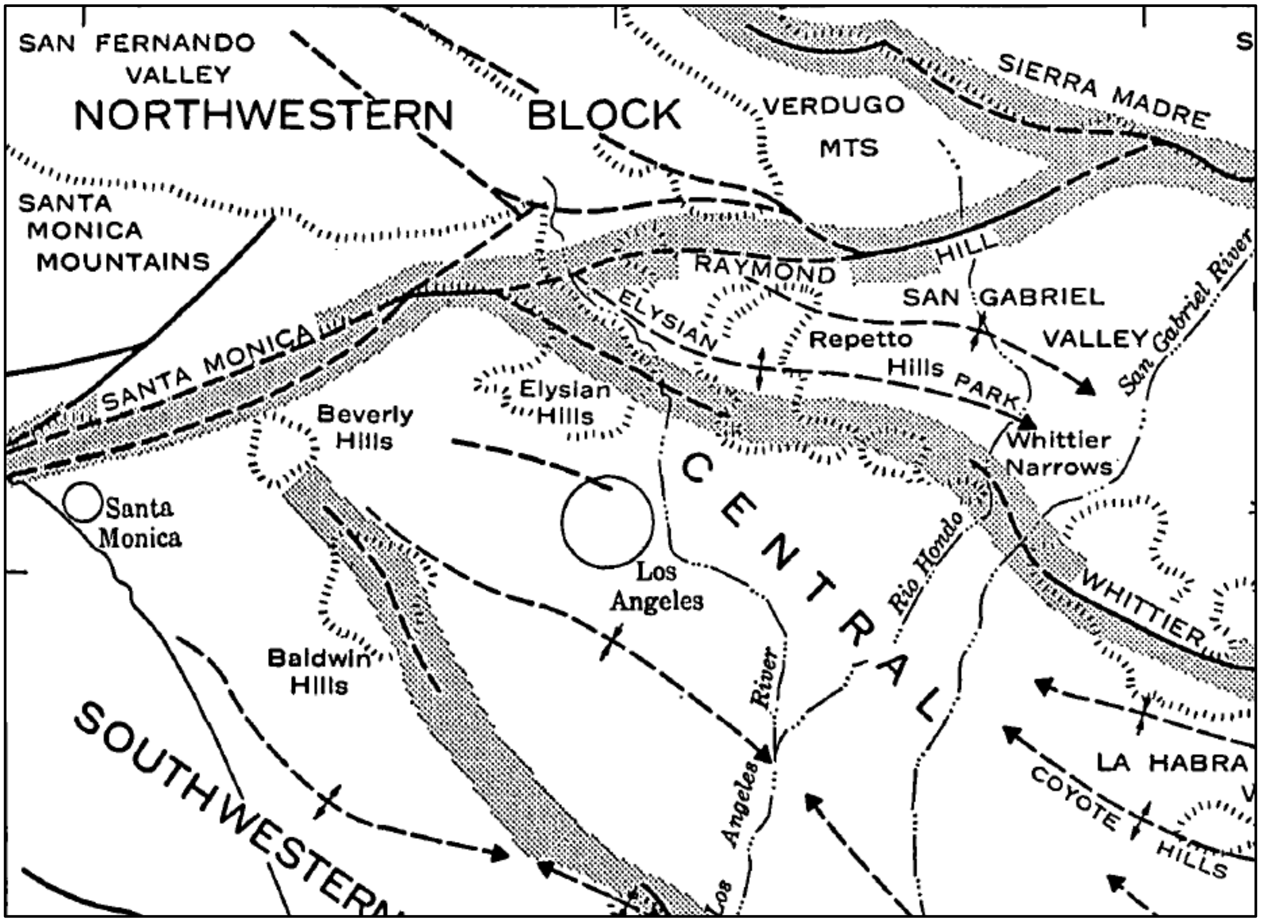

Figure 3 - Fault map from Yerkes *et al.* (1965) showing the "Santa Monica Fault Zone" consisting of two subparallel faults along the base of the Santa Monica Mountains.

Johnson (1932)

An important early study of the Santa Monica Fault was performed by Johnson (1932) as part of his geologic investigation of the Quelinda Estate in Pacific Palisades (Figure 4). The estate property, now subdivided into residential lots, is located at the top of the cliffs, east of the mouth of Potrero Canyon. Johnson (1932) performed detailed geologic mapping of the cliff faces around Potrero Canyon and along the coast to assess potential hazards related to landsliding and faulting. The fault exposed in the canyon cliff face was referred to as the "Potrero Fault" in this study.

Detailed study of this exposure indicated the Potrero Fault consists of a lower north-dipping fault strand and a near-vertical upper strand extending up to the surface from this lower fault. Up to 100 feet of offset within the Pleistocene sediments was measured, with the uppermost Pleistocene terrace gravels, which are the youngest sediments at the site, offset "at least four feet" (Figure 5). Johnson and his associates studied the uplifted terrace surfaces east of Potrero Canyon for geomorphic indicators of fault movement, studied stream gradient changes in the adjacent canyons, and performed two different types of geophysical surveys in an effort to map out the near-surface trend of the fault. They conclude the data collected "are almost sufficient to classify this fault as geologically active."

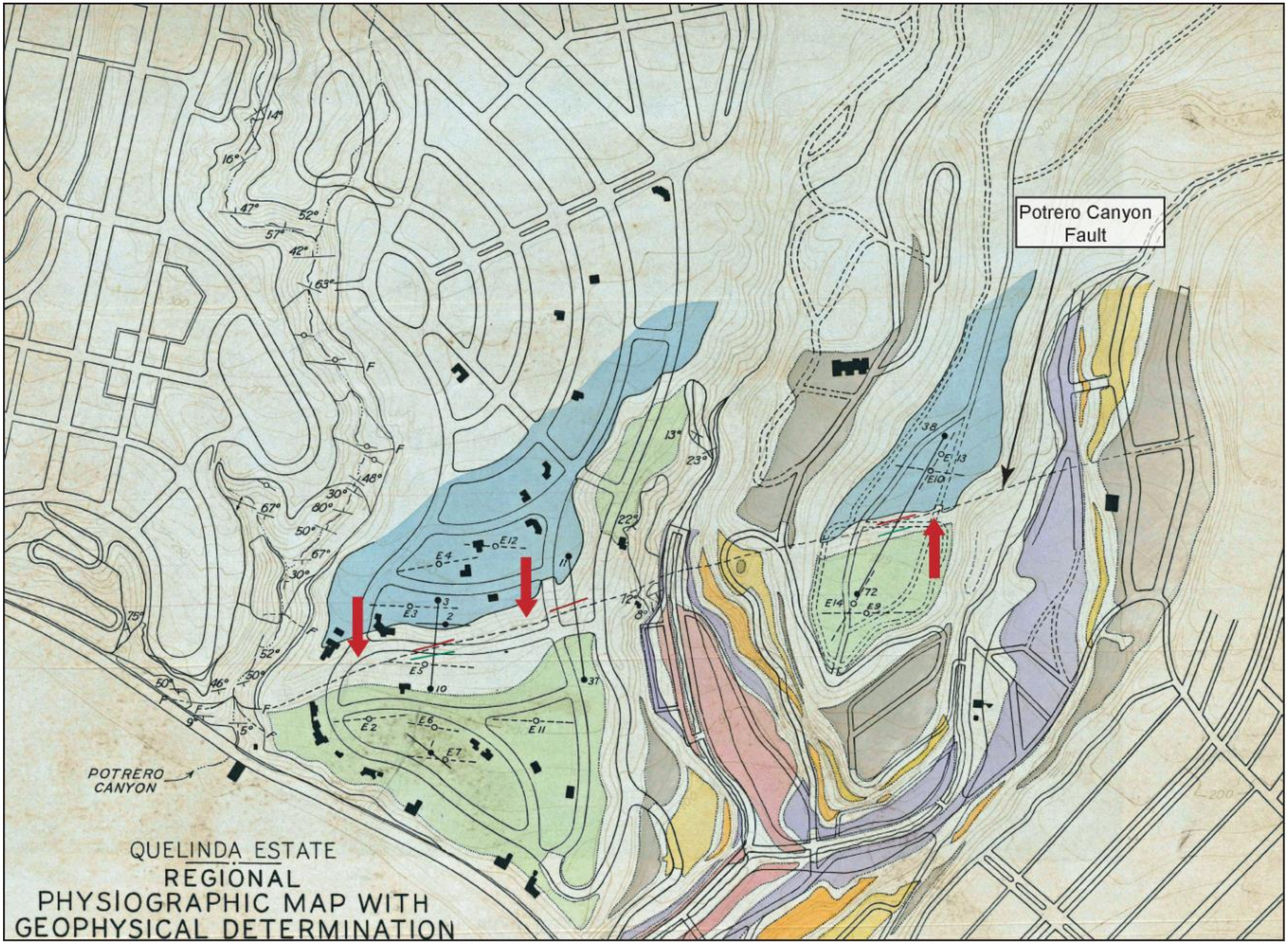

Figure 4 – Map showing various terrace surfaces (colored) and approximate surface trace of the "Potrero Fault". Numbered solid and dashed lines are geophysical transects, red and green line segments are probable fault crossing locations based on geophysical data. Red arrows point to breaks in slope between terrace surfaces interpreted as fault scarps. (modified from Johnson, 1932)

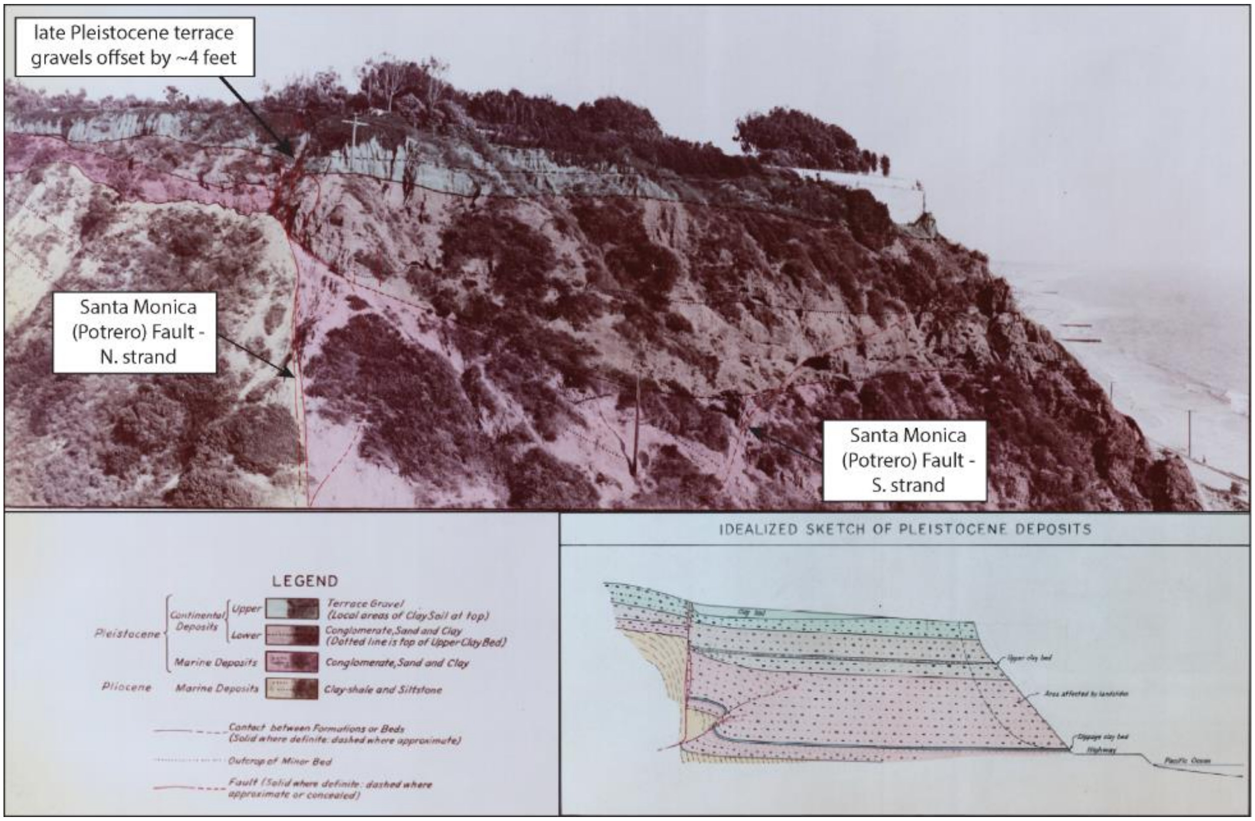

Figure 5 – Annotated photograph of the east wall of Potrero Canyon (c. 1932) showing steeply dipping northern strand and low-angle southern strand of the Santa Monica ("Potrero Fault"). Lower right is a simplified illustration of the stratigraphy and structure exposed in the canyon wall. (modified from Johnson, 1932)

Hill (1979) and Hill *et al*. (1979b)

Hill (1979) further described the fault exposure at Potrero Canyon. Here he reported slickensides in expansive clay gouge and striations on adjacent cobbles are parallel to the fault plane suggesting the most recent movement on this fault was reverse, north-side-up. Additionally, farther east, Hill (1979) suggested a series of prominent discontinuous scarps with a maximum height of 30 to 45 feet beginning at University High School and extending east toward Beverly Hills are associated with faulting. He observed the scarp is associated with several springs at the University High School campus and a regional groundwater barrier with notably higher groundwater elevations north of the scarp further suggesting the presence of a fault in the shallow subsurface. However, at that time Hill (1979) stated "the relationship of the probable fault at University High School to other faults in the area is not clear."

Between Beverly Hills and Hollywood, Hill *et al*. (1979b) reviewed available surficial geologic data, as well as oil well, gravity, groundwater, and historic precision leveling survey data to evaluate the location and activity of the Santa Monica Fault. Based on these data, they identified a zone of differential subsidence between 100 and 400 meters wide extending from western Beverly Hills across the alluvial plain to Hollywood. They inferred the near-surface trace of the Santa Monica Fault was located within this subsidence anomaly zone.

Crook *et al*. (1983) and Crook & Proctor (1992)

Crook *et al.* (1983) and Crook and Proctor (1992) provide a summary of early unpublished geologic data collected from various localities along the Santa Monica Fault. Three investigation sites are located within the study area. The first is a foundation excavation at the intersection of Wilshire Boulevard and Bundy Drive. Here observations made in the excavation and in borings at the site, provided evidence of a groundwater barrier in late Pleistocene sediments. Groundwater was reported to be about 15 feet deep northwest of the Wilshire-Bundy intersection, and up to approximately 70 feet deep southwest of the intersection. Additionally, a pump test performed on the southwestern property suggested a second groundwater barrier approximately 350 feet south of Wilshire Boulevard. Crook and Proctor (1992) note this site "…coincides with a geomorphic feature—possibly a scarp on a branch of the Santa Monica fault—as seen on 1927 Fairchild aerial photographs and old topographic maps."

The second site is University High School where Crook *et al*. (1983) excavated a total of five exploratory trenches to look for evidence of faulting in the shallow subsurface. They report faulted sediments were only observed in one trench. Here, the authors observed two well-defined south-dipping faults lined with clay gouge. North of the faults, the trench exposed distal alluvial fan sediments consistent with the alluvial fans emanating from the Santa Monica Mountains to the north. South of these faults, they describe dark colored, very clayey sediments, interpreted as a colluvial wedge and sag pond deposits that may have formed at the base of the fault scarp. Drag features exhibited by several of the contacts in the footwall suggest south-side down, normal offset; however; significant lateral slip is also suggested by the complete lack of similarity between sedimentary units across the faults.

Lastly, Crook *et al*. (1983) excavated two fault trenches at the base of the noticeable scarp along the southern property boundary of the Veteran's Administration Hospital along Ohio Avenue. Both trenches exposed numerous features associated with faulting within the older alluvial fan deposits. None of these features were traced up to or through a strong argillic soil horizon coincident with the upper fan surface. The authors interpreted these fault features as the Santa Monica Fault because they exhibit a N80°E to N85°E trend similar to the prominent scarp feature. They posit these features do not form sharp fault planes, nor do they show clear offsets because faulting may have occurred when the alluvial sediments were much less consolidated than they presently are. They note similar diffuse and subtle features were observed in trenches excavated across some of the surface faults that ruptured in the 1971 San Fernando earthquake.

McGill *et al*. (1987) and McGill (1989)

McGill *et al*. (1987) provide a further description of the key exposure of the fault previously documented by Johnson (1932), which is now buried, in the Pacific Palisades area. The authors note the Potrero Canyon Fault, which they state "is a strand of the Santa Monica fault system," strikes approximately N80°E and dips between 43° and 55° to the north with a near-vertical upper strand dipping 81° north. Pliocene marine siltstone is exposed north of the fault and upper Pleistocene marine terrace sands and non-marine alluvium are exposed to the south. Striations observed along the fault plane are generally along dip, suggesting the most recent movement along this strand of the fault was north side up reverse motion. The sub-vertical strand of the fault was traced to within 4 meters of the ground surface. In his geologic map of the Pacific Palisades area, McGill (1989) shows the surface trace of this fault cutting the marine terraces and trending northeasterly from Potrero Canyon towards Santa Monica Canyon.

Dolan and Sieh (1992), Dolan and Pratt (1997), and Dolan *et al*. (2000a)

Dolan *et al*. (2000a) performed a site-specific paleoseismological fault study, coupled with previous geomorphologic mapping by Dolan and Sieh (1992) and high-resolution seismic reflection profile data (Dolan and Pratt, 1997), to evaluate seismic hazards associated with the Santa Monica Fault. Unlike the Hollywood Fault, which is located near the mountain front, the Santa Monica Fault is expressed as a series of *en echelon* scarps 3-4 km south of the mountain front in the Quaternary alluvial fan deposits emanating from the Santa Monica Mountains. Dolan and Sieh (1992) note the "consistent south-facing scarps…coupled with uplift of the Santa Monica Mountains, indicate a strong contractional component of deformation along the fault." They further state the left-stepping *en echelon* pattern of the surface trace west of Beverly Hills suggests there is also a component of lateral motion, which is most likely left-lateral given the sense of motion of other faults in the system.

Two trenches were excavated across the prominent 5-meter-high south-facing scarp at the southern property boundary of the Veteran's Administration (VA) Hospital Grounds (Plate 1) by Dolan *et al*. (2000a). The first and longest trench (T-1) is 112 meters long and a second small trench (T-2) was opened 5 meters west and parallel to T-1. Trench T-1 was excavated approximately 50 meters east of the two Crook *et al*. (1982) trenches and extended much farther up the scarp. The general stratigraphy observed in the previous trenches was similar to that documented in this study, with relatively flat-lying young fan sediments on-lapping south-dipping late Pleistocene to early Holocene alluvial fan deposits. Four distinct stratigraphic packages were identified in T-1 based on internal consistency, sedimentary structures, and soil development (Figure 6). The units were dated using pedogenic analyses and radiocarbon dating of detrital charcoal samples, and indicate the packages range in age from Holocene (Package I) to late Pleistocene (Packages II-IV). Four distinct faults (Faults 1 through 4) were exposed in T-1 (Figure 7). Faults 1 and 2 dip steeply to the south, exhibiting south-side down normal separations. Fault 3 consists of a zone of steeply north-dipping faults with a significant 3-10 cm wide gouge zone along the main strand in the trench bottom. This gouge zone strikes N76°E and dips 74° north. This fault was also observed in T-2 where it occurs as three distinct strands defining a positive flower structure. Major differences in stratigraphy across an area of T-1 that was not fully excavated due to a buried electrical conduit led the authors to infer the presence of Fault 4. The four faults all cut Pleistocene sediments; however, none of the faults offset the flat-lying Holocene sediments (Package I) at the southern end of the trench. Additionally, stratigraphic evidence for strike-slip offset is most common throughout the faults exposed in the trenches, with "subordinate, and locally variable, vertical components of motion" (Dolan *et al*., 2000a).

Based on their observations, the authors conclude T-1 contains evidence of at least six surface rupturing earthquake events in about the last 50 k.y. The two most recent are of most concern for the present fault evaluation. Although not directly observed because of the buried electrical conduit, the most recent event recorded in the trench sediments (Event F) is believed

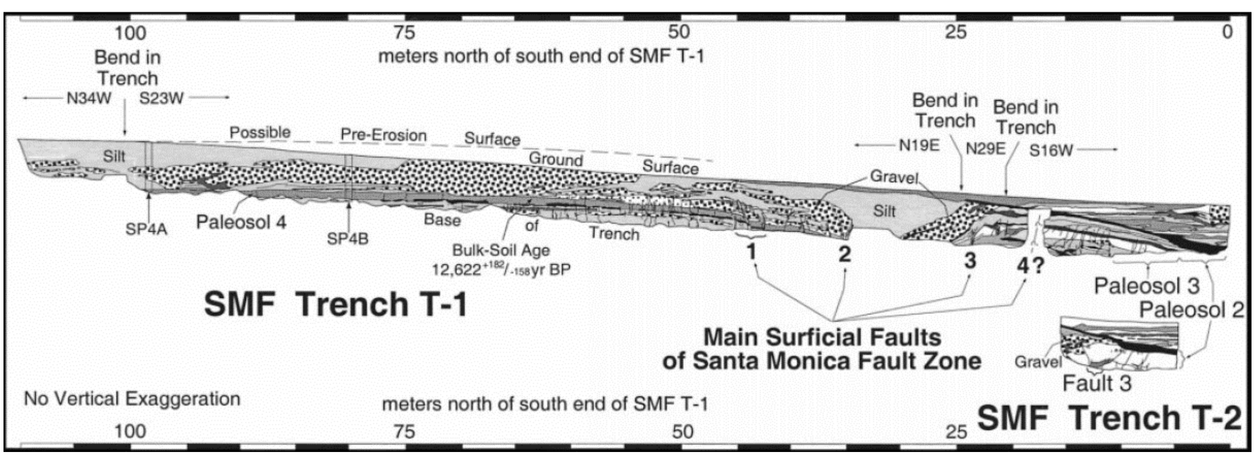

Figure 6 - Log of east wall of the Dolan *et al*. (2000b) trench T-1 at the Veteran's Administration Hospital property. Major paleosol markers and four principal fault strands indicated. Horizontal scale is distance, in meters, measured from the south end of the trench (modified from Dolan, 2000b).

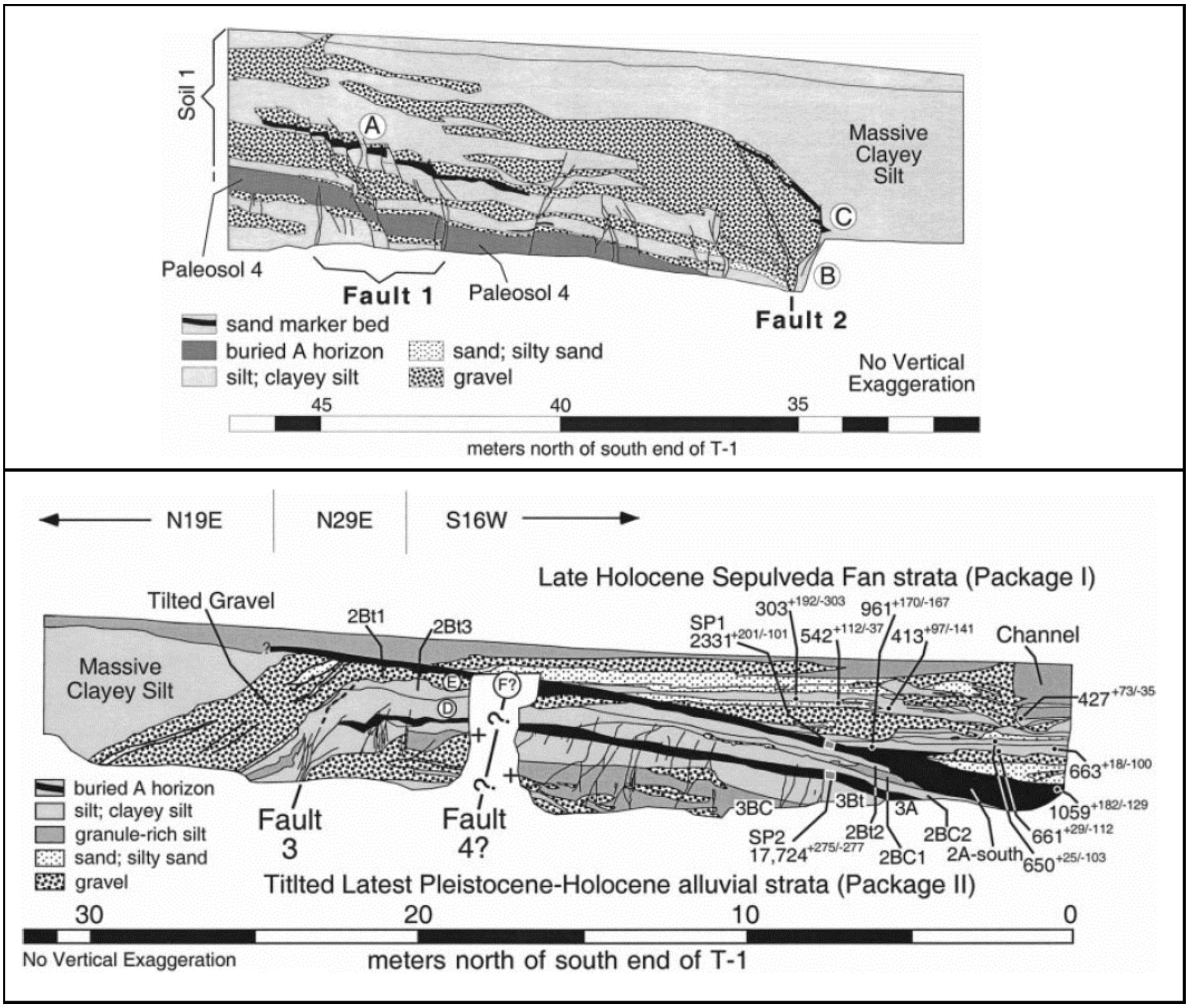

Figure 7 - Detail of central (top) and southern (bottom) walls of the Dolan *et al*. (2000b) trench T-1 at the Veteran's Administration Hospital. Circled letters represent structural or stratigraphic features used to interpret paleo-surface ruptures. **Top:** Deformed sediments associated with faults 1 and 2. **Bottom:** Disrupted south-dipping strata progressively overlain by flat-lying sediments of the Sepulveda fan. Solid black layers are buried A horizons. Small black dots show locations of detrital charcoal samples. Plus symbols mark the top of a displaced pebbly layer used to postulate the existence of fault 4. (modified from Dolan *et al*., 2000b)

by the authors to have occurred between 1 and 3 k.y. ago on Fault 4. The penultimate event, which is evidenced by offset layers and the presence of a colluvial wedge within Package II, likely occurred about 10-16 ka. Using the approximate dates for the earthquake events on Faults 3 and 4, the authors calculate an average recurrence interval for surface-rupturing earthquakes in the Holocene-latest Pleistocene of about 7-8 k.y.

Kenney GeoScience (2011, 2012, 2013, 2014)

Between 2011 and 2014, Kenny GeoScience (KGS) conducted various geologic evaluations of the eastern Santa Monica Fault Zone for the Beverly Hills Unified School District chiefly consisting of reviewing previously published and unpublished regional geologic reports and mapping, as well as several site-specific geologic and fault investigations performed in Beverly Hills and the Century City area (KGS, 2011, 2012, 2013, 2014). KGS also conducted a geomorphic analysis of the Cheviot Hills region looking for evidence of active faulting recorded in the regional landforms.

Based on their review of regional geologic and tectonic studies, KGS (2011) indicated the "Santa Monica Fault Zone" consists of a northern and a southern strand (Wright, 1991; Tsutsumi *et al*., 2001). The southern strand, which initially formed during the Miocene as a normal fault, is referred to by Wright (1991) as the "Santa Monica Fault". The fault transitioned to a dominantly reverse sense of motion during the Pliocene as the tectonic regime of the Los Angeles Basin evolved from extensional to compressional; however, because this southern fault is overlain by early Pleistocene sediments that are not offset, Wright determined it was not active. The northern strand, which Wright calls the "Potrero Canyon Fault", is what most workers, including this report, refer to as the Santa Monica Fault. This strand extends up to within a few feet of the surface in several locations, including the VA hospital and is associated with a series of scarps and lineaments within the Pleistocene alluvial fan deposits throughout the study area.

KGS also conducted a thorough review of several site-specific geologic and fault studies within the Cheviot and Beverly Hills areas. The most extensive of these geologic studies is the Westside Subway Extension fault investigation (Parsons Brinckerhoff, 2011). This fault investigation was performed for the Los Angeles Metro's proposed Westside Subway Extension Project (discussed in further detail later in this report) mapped several fault strands in the western Beverly Hills/Century City study area. Using continuous core boring/CPT transects, Parsons Brinckerhoff (2011) recognized several northeast-trending faults associated with the Santa Monica Fault Zone along Santa Monica Boulevard and interpreted a northwest-trending zone of faults along the base of the West Beverly Hills Lineament (WBHL) of Dolan and Sieh (1992). Based on their geologic observations, stratigraphic correlations, and relative dating of the soils collected in the core samples, Parsons Brinckerhoff concluded both fault zones were active by State of California standards.

Later, a fault investigation was conducted at Beverly Hills High School (Leighton Consulting, Inc., 2012a,b,c) to address faults identified in the Parsons Brinckerhoff (2011) study, which were mapped across the school campus (discussed in further detail later in this report). The Leighton Consulting (2012a,b,c) studies consisted of core borings/CPT transects similar to the Parsons Brinckerhoff (2011) study, but also incorporated fault trenching, which was not performed by Parsons Brinckerhoff. Fault trenches and boring transects were excavated across both the faults mapped along the WBHL and the zone of faults associated with the SMFZ along the northern end of the school. The WBHL data indicated no significant faulting along the lineament. The data within the SMFZ indicated a major fault at depth, which extended to the surface. A fault trench across this feature showed a fault offsetting tilted late Pleistocene sediments; however, Leighton Consulting, Inc. (2011c) concluded this fault was inactive.

Based on their detailed review the data, KGS (2011) stated the conclusions of the Parsons Brinckerhoff (2011) study were not supported by the geologic data. They indicated the faults mapped by Parsons Brinckerhoff along the WBHL do not exist and those paralleling Santa Monica Boulevard do exist, but are not active. KGS named this latter fault zone, which extends from the Mormon Temple to the Los Angeles Country Club and into western Beverly Hills, the Santa Monica Boulevard Fault Zone (SMBFZ) (Figure 8).

Additional fault investigations and other subsurface data continued to be collected for projects in the Cheviot Hills area, which KGS reviewed and incorporated into a regional geologic model for the area. These chiefly included fault investigations at 10000 Santa Monica Boulevard

(Geocon West, 2012) El Rodeo Elementary School (Leighton Consulting, Inc., 2015, 2016), and 9900 Wilshire Boulevard (Geocon West, 2014b).

The most significant component of the KGS model was the development of a Quaternary stratigraphic framework for the Cheviot Hills area based on their previous geomorphic study and the soil sample descriptions collected from the numerous borings drilled and fault trenches excavated as part of these investigations (KGS, 2012, 2013, 2014). The upper 200 feet of sediment underlying the Cheviot Hills was examined and sub-divided into four distinct depositional units and used to create a new geologic map of the Cheviot Hills (Figure 9). The oldest unit identified is the basal San Pedro Sequence (SPS), which includes the marine San Pedro and Lakewood Formations and some overlying non-marine sediments. The upper boundary of the SPS is defined by an erosional surface and locally an angular unconformity with the overlying sediments. KGS (2013) believes the Lakewood formation interfingers with the non-marine portions of the upper SPS and lower Cheviot Hills Deposits units. The SPS is estimated to be a minimum of about 600,000 years old. Overlying the SPS is a series of non-marine distal alluvial fan sediments referred to as the Cheviot Hills Deposits (CHD). Overall, these deposits consist of interfingering fining-upward sequences, mud and debris flows, and buried paleosols. Relative age dating of the paleosols suggests this unit ranges in age from 540,000 years to 150,000 years old. Next is the Benedict Canyon Wash Deposits (BCWD), which are subdivided into younger $BCWD_1$ and older $BCWD_2$ units. The $BCWD_2$ unit consists of alluvial fan sediments deposited along the southern margin of the Santa Monica Mountains prior to the uplift of the Cheviot Hills. These deposits are estimated to range in age from at least 340,000 to about 550,000 years old. The younger $BCWD_1$ sediments were deposited within drainages incised into the $BCWD_2$ fans. Soil age studies on $BCWD_1$ deposits exposed in the fault trench at 10000 Santa Monica Boulevard helped refine the age of the unit, suggesting it was deposited between 170,000 and 370,000 years ago (KGS, 2014). The youngest stratigraphic unit is the latest Pleistocene through late Holocene Brown Canyon Wash deposits (BrCWD). This alluvial unit lies stratigraphically above the $BCWD_1$ deposits. Sediments within this unit were identified and mapped within Brown Canyon in the Century City area and other drainages in the study area, which emanate from the Santa Monica Mountains. Age estimates based on soil profile evaluations indicate the BrCWD range in age from 40,000 years to the present. This stratigraphic framework was subsequently used by several workers conducting fault studies in this region.

KGS also evaluated the topographic scarps first described by Dolan and Sieh (1992), as well as the remnant fan surfaces and current stream drainage patterns within the Cheviot Hills noting a marked change across the strongly linear scarp that parallels Santa Monica Boulevard in the Century City area (KGS, 2011). The faults along this scarp are referred to by KGS as the "Santa Monica Boulevard Fault" (SMBF). This portion of the SMFZ trends about N50°E from the Mormon Temple in Westwood to the West Beverly Hills Lineament (WBHL) (Plates 1 and 2). North of the SMBF, the generalized topographic contours are typically evenly spaced and retain a characteristic alluvial fan morphology, suggesting these deposits were not appreciably deformed since deposition. South of the SMFL, the contours in the Cheviot Hills appear to record local deformation as they generally trend perpendicular to those north of the lineament forming an antiformal structure. Additionally, KGS identified a possible ancestral drainage that flowed southwesterly across the Cheviot Hills in the region of the SMBF.

Considering all the data they collected and evaluated, KGS (2012, 2013, 2014) disagreed with the several of the conclusions of the Parsons Brinckerhoff (2011) report, and therefore proposed their own regional tectonic model. They state no conclusive evidence was provided to prove any faults in the Cheviot Hills area are active. They stated the data indicates the faults mapped by Parsons Brinckerhoff along Santa Monica Boulevard do exist, but they are not active.

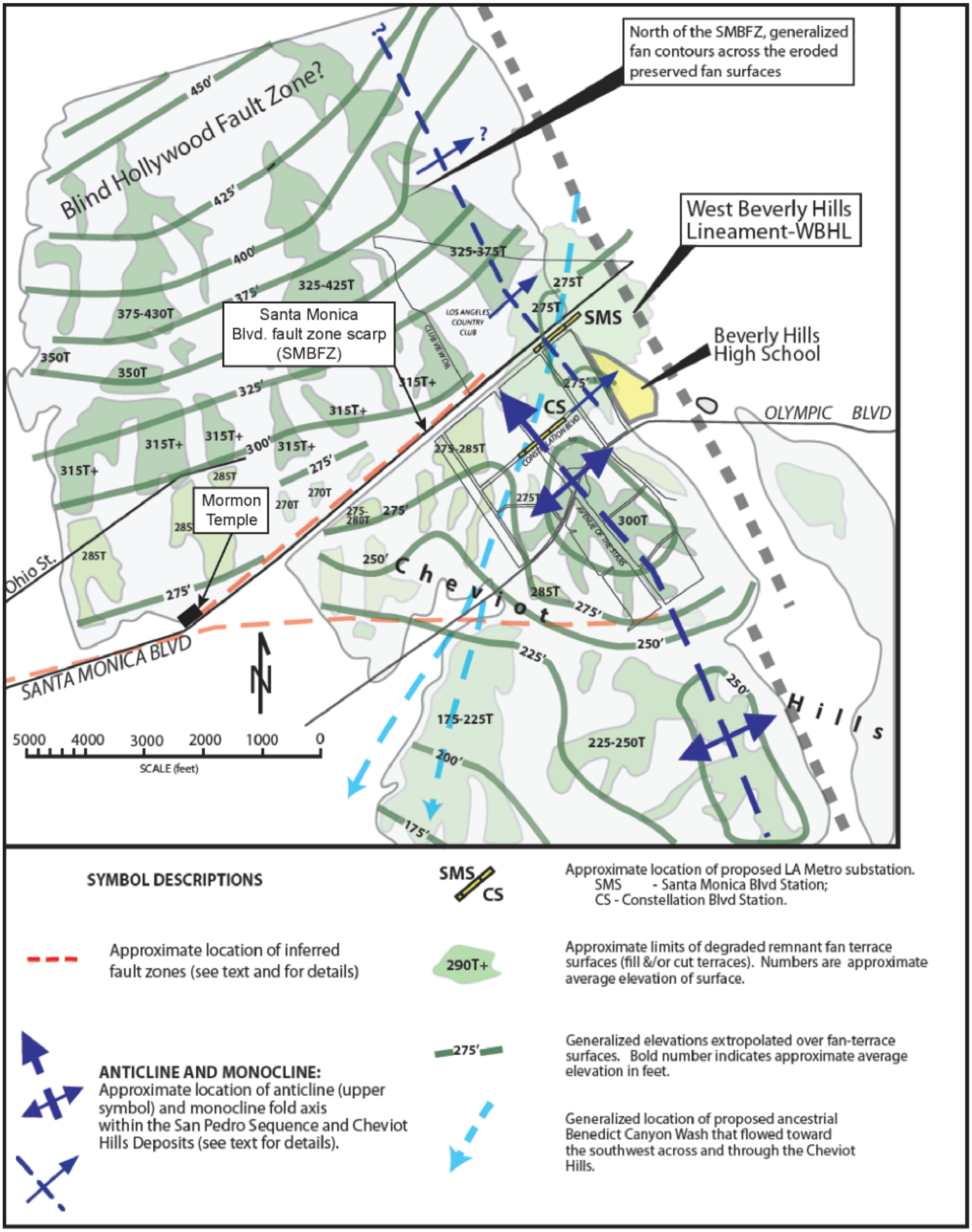

Figure 8 – Simplified contour map of terrace surfaces in the Cheviot Hills from KGS (2012, Plate ES-13)

KGS (2011) refers to this fault zone, which extends from the Mormon Temple to the Los Angeles Country Club and into western Beverly Hills, as the "Santa Monica Boulevard Fault Zone" (SMBFZ) (Plate 1 and Figure 8). Similar to the fault strands mapped at Potrero Canyon and observed by Dolan *et al*. (2000a), KGS postulates the SMBFZ consists of various sub-vertical secondary upper plate faults rooting into a blind low-angle basal oblique reverse fault at depth. Based on the subsurface data reviewed, they identified two major sets of faults. The first set parallels Santa Monica Boulevard and is sub-divided into three zones: Fault Zone A, Fault Zone F, and Fault Zone G (Figure 10). Zone A is interpreted as a series of primarily strike-slip faults that trend northeast and parallel to the strong geomorphic scarp identified by Dolan and Sieh (1992) along Santa Monica Boulevard and turning northeasterly through the country club. KGS (2014) proposes this fault zone may continue on trend across the WBHL and the northern Beverly Hills alluvial plain to connect with the western Hollywood Fault (Plate 1). Zones F and G are subparallel and south of Zone A, and some splays of Fault Zone F may continue across the WBHL and extend across the Beverly Hills alluvial plain where they may connect with the blind North Salt Lake Fault and the Hollywood Fault (Plate 1). The Fault Zone G strands are interpreted from relatively sparser data set then other areas, and therefore, the general strike, number of faults, and sense of offset are not well constrained. East of BHHS and roughly orthogonal to Fault Zones F and G, KGS identified a set of northwest-trending faults, which do not parallel the regional trend of the WBHL. They indicate displacements across the Zone H faults appear to be down to the east, but the activity of these faults is not well known. Based on the postulated strike of Fault Zone H, it is possible it could connect with strands of the Newport-Inglewood Fault identified by Erickson and Spaulding (1975) east of the WBHL.

KGS (2014) classified each of the above fault zones as either "likely inactive" or "activity unknown" based on subsurface data and age of the oldest unfaulted unit. However, KGS noted there are some areas where the existing data is not sufficient or too sparse to provide good enough stratigraphic resolution with which to assess activity. First, they state the base of the BrCWD does not appear offset across Fault Zone A, suggesting this fault zone is "likely inactive". They also reviewed subsurface data east of the country club and WBHL where the base of the BrCWD unit was also reportedly not offset by the Zone F faults. Lastly, due to the relatively fewer number of subsurface data points there is sufficient uncertainty in the subsurface data for Fault Zones G and H. As such, KGS classifies both as "activity unknown".

Additionally, KGS (2014) concluded the Cheviot Hills south of the SMBFZ are undergoing active folding, albeit at a low to very low rate. They note the top of the San Pedro Formation and a 200ka fan surface are deformed equally, suggesting the folding initiated in the late Pleistocene. Their model postulates the Newport-Inglewood Fault Zone (NIFZ) extends under the eastern Cheviot Hills and beneath the Santa Monica Fault Zone. Movement of the tectonic block south of the SMFZ and west of the NIFZ causes uplift and folding in the Cheviot Hills and creation of a gently east-dipping monocline north of Santa Monica Boulevard. Thus, the WBHL was formed by folding and subsequent erosion by Benedict Creek, not surface faulting. KGS states this model does allow for surface faults associated with the NIFZ to exist south of the north-dipping blind strand of the SMFZ and farther east of the WBHL.

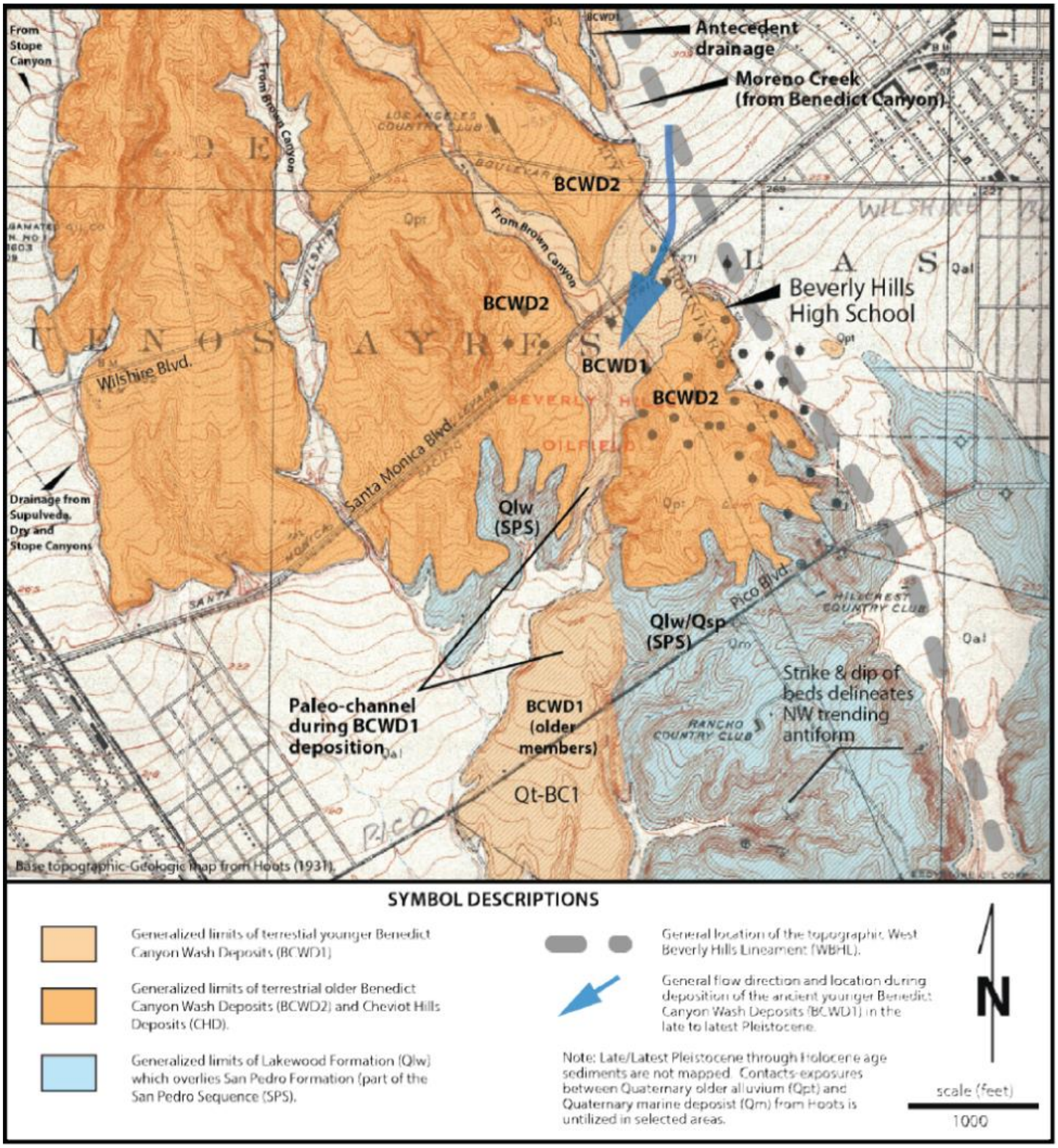

Figure 9 - Generalized geologic map of the Cheviot Hills from KGS (2014, Figure 15).

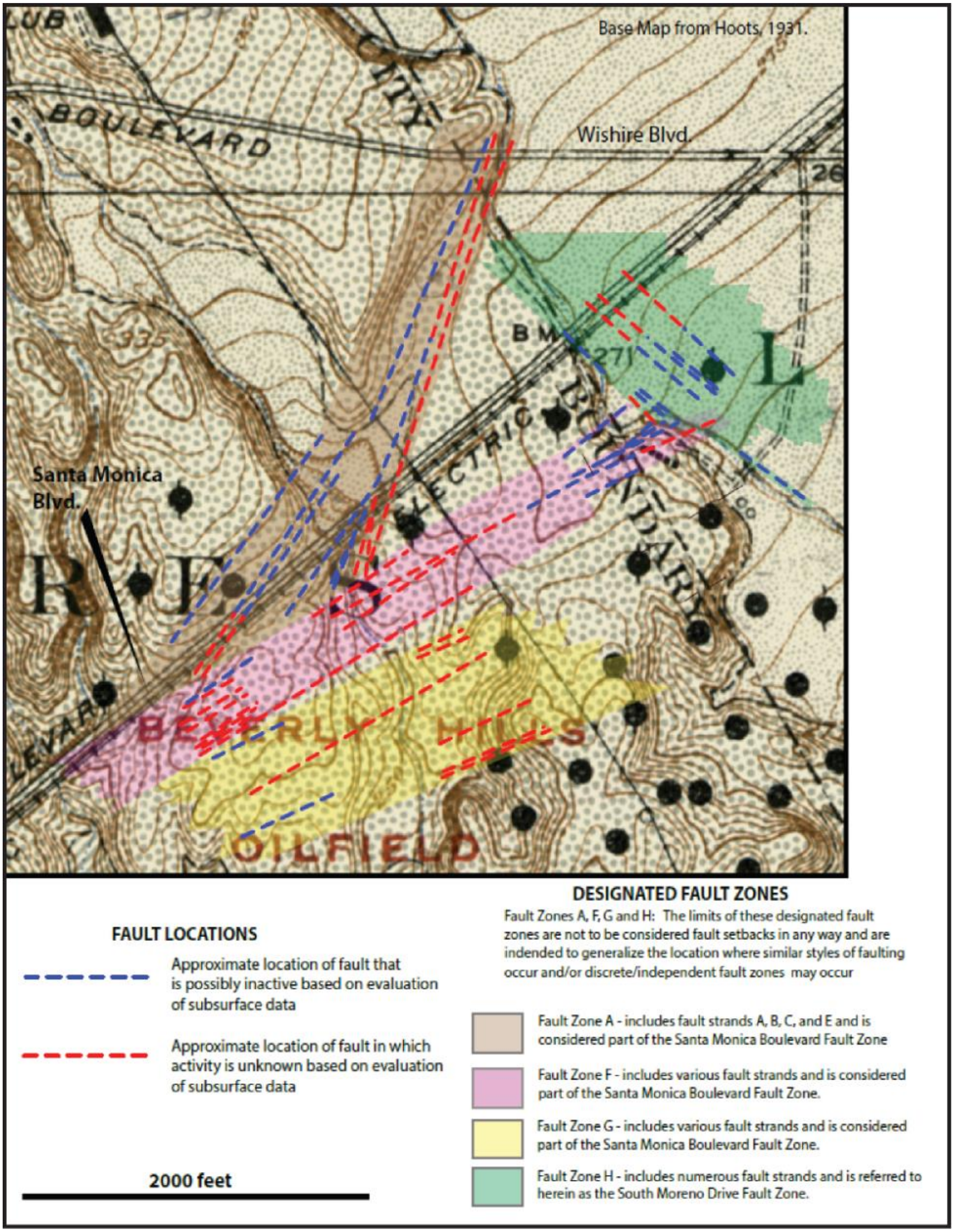

Figure 10 - Major fault zones identified by KGS and discussed in text. (base image, symbology, and descriptions from KGS, 2013, Figure 1)

Kenney GeoScience (2016)

This report features a much broader study area than previous KGS reports, which primarily focused on the Century City/Cheviot Hills area. This study instead provides a larger regional tectonic model covering the area from Pacific Palisades in the west to Hollywood in the east to the northern Baldwin Hills to the south. KGS states a major change occurred along the southern boundary fault zone of the Transverse Ranges at approximately 1 Ma, which changed the style of faulting from mainly oblique blind reverse faults to more dominantly left-lateral strike-slip faulting. At this time, they indicate the Potrero Canyon-Santa Monica Boulevard Fault Zone ("Santa Monica Fault Zone" of this report) formed along with the postulated "cross faults", which connect this fault zone with the Hollywood Fault to the northeast (see Plate 1). Also around this time the northern end of the Newport-Inglewood Fault Zone (NIFZ) migrated north as far as the SMBFZ. This system persisted until about 200,000 years ago when KGS suggests the SMBFZ and the associated "cross faults" became inactive. About this time they propose a new strike-slip fault, the Potrero Canyon Fault East (PCFE), developed to accommodate left-lateral slip no longer taken up by the SMBFZ (Plate 1). Subsequent to its formation, the portion of the NIFZ north of the PCFE became structurally disconnected from the main fault zone to the south. Continued northward movement of the tectonic block west of the NIFZ and south of the SMBFZ initiated compressional folding and uplift of the southern Cheviot Hills at this time, and which is still ongoing. As a result, KGS states the PCFE remains an active fault.

The KGS report contains a fault activity map of the northwestern Los Angeles Basin depicting active, inactive, and potentially active (i.e. "Holocene activity unknown") strands of the Santa Monica, Hollywood, and Newport-Inglewood Fault Zones.

SELECTED GEOTECHNICAL STUDIES AND FAULT INVESTIGATIONS

(for referenced localities, see Figures 11 and 14)

Subsurface geologic and fault investigation studies related to various proposed developments and environmental monitoring have been completed throughout the study area. Pertinent studies were reviewed for data relating to the evaluation of the Santa Monica Fault Zone and are summarized below with locations depicted on Figures 11and 14.

Locality 1 - 211 N. Alma Real Drive

Grover-Hollingsworth and Associates, Inc. (2014b) conducted a subsurface fault investigation for a proposed residential property located atop a prominent scarp in the terrace surface east of Potrero Canyon. Geologic mapping by others (Hoots, 1931; McGill, 1989; KGS, 2016) shows a strand of the Santa Monica Fault Zone trending across the area of this property (Fig. 11). For the investigation, they excavated and logged three overlapping trenches oriented perpendicular to the mapped fault trace. These trenches exposed continuous layers within the Pleistocene marine terrace deposits. No evidence of faulting was observed. Based on the local geomorphology and the findings of their investigation, the consultants state the subject fault strand is most likely located just south of the subject property.

Locality 2 - 12054 Wilshire Boulevard

In 1997, a groundwater monitoring program was initiated at a gas station located at 12054 Wilshire Boulevard (Figure 11 – locality 2). Approximately 45 groundwater monitoring wells were installed at the site and to the south (down-gradient) to determine the hydrogeology of the site and monitor the groundwater remediation program. Based on the subsurface data collected from these wells, the consultants identified two faults, which act as groundwater barriers. The groundwater elevation data shows an approximately 60-foot drop in groundwater level across the northern strand and about a 15-foot change in the groundwater surface across the southern strand. (Worley Parsons Komex, 2009). A similar sharp drop in depth to groundwater was reported in Dolan *et al*. (2000a) on a site at the northwest corner of Wilshire Boulevard and Bundy Drive, immediately adjacent to this site. Additionally, a strand of the SMFZ was observed in an excavation for a building at the same intersection (G.A. Brown, 1993, pers. comm., reported in Dolan *et al*., 2000a).

Locality 3 - University High School

MACTEC (2004a) performed an initial subsurface fault investigation at the University High School campus in Los Angeles to determine the location and relative activity of the Santa Monica Fault, which is mapped at the site (Hill, 1979; Crook *et al*., 1983; Dolan and Sieh, 1992). The site is bisected by a northeast-southwest trending scarp that ranges from 12 to 14 meters in height. Along the base of this scarp, there are numerous natural springs, which are likely related to faulting at the site.

The investigation consisted of drilling 26 continuous core borings and advancing 42 cone penetrometer tests (CPTs) along four linear transects across the inferred trace of the Santa Monica Fault. Additionally, the consultants performed a high-resolution seismic reflection survey along the western site boundary (Westgate Avenue) to explore this area, which is less accessible to drilling equipment and to extend the depth of exploration below that achieved by the borings and CPTs. Based on the samples collected from the borings the consultants identify three major sedimentary units: Holocene alluvium, Pleistocene alluvium, and Pleistocene near-shore marine deposits.

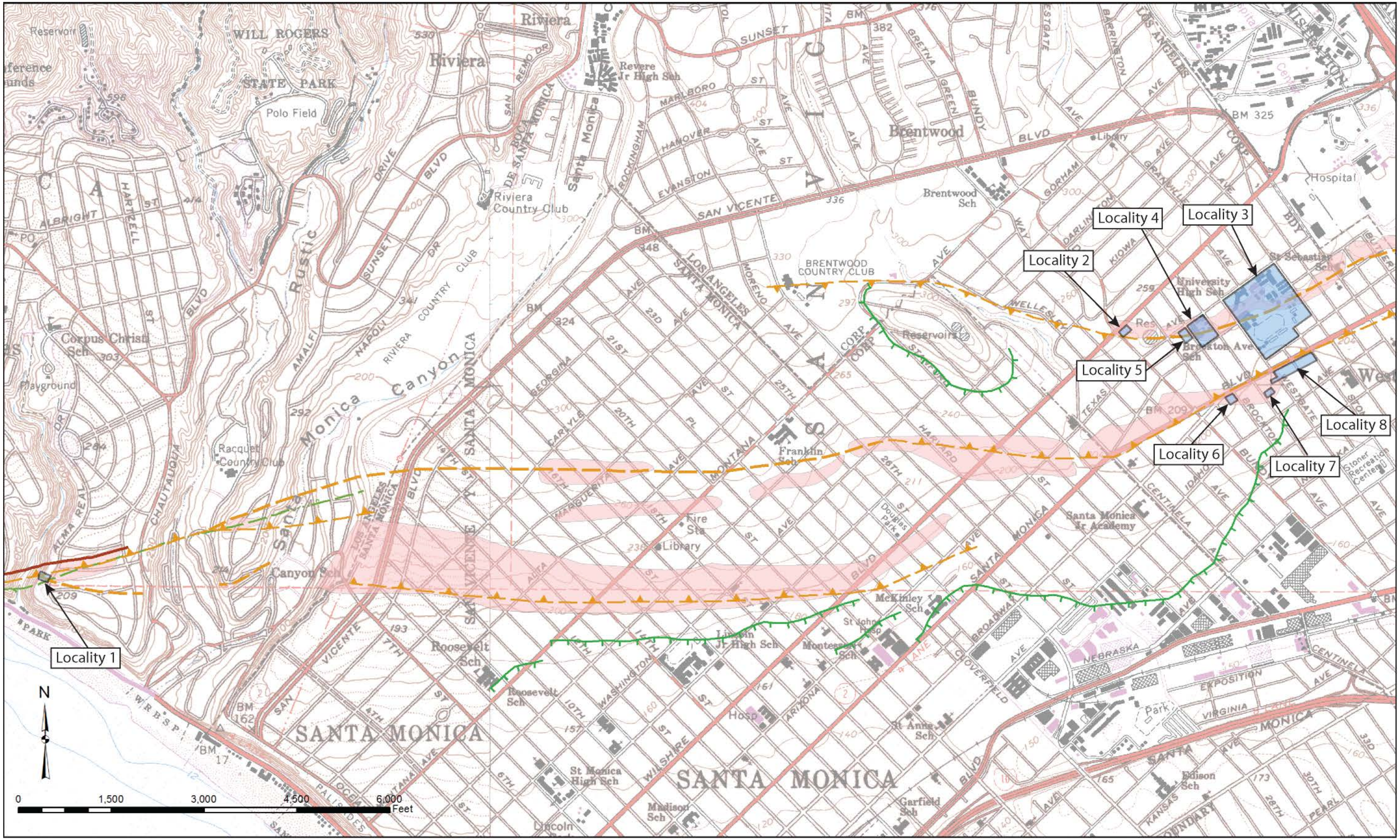

Figure 11 - Study site boundaries (light blue boxes) where investigations provide data relevant to evaluation of the Santa Monica Fault Zone west of Interstate 405 (localities 1 through 8, discussed in text). See legend on Plate 1 for fault types and mapping sources. Shaded area is the approximate limit of "fold scarps" identified by Dolan *et al*. (2000a).

Based on stratigraphic anomalies identified along the four transects, the consultants identified several active traces of the Santa Monica Fault in a zone trending N50°E to N55°E (Figure 12). In general, the faults identified dip steeply to the south with normal south-side down sense of slip (Figure 13). Additionally, significant lateral displacement is suggested by thickness changes or truncation of sedimentary units across the fault zone.

MACTEC (2007) returned to the site a few years later to perform a supplemental fault study focusing on the southern and northern portions of the campus, which were not adequately investigated in their previous study. For this investigation, the consultants drilled an additional 20 continuous core borings and advanced an additional 23 CPTs along three new transects. No additional faults were identified other than those previously reported in the 2004 study.

Locality 4 - Brockton Avenue Elementary School

Two blocks west of University High School (Figure 11 – locality 3), MACTEC (2006) performed another fault investigation of the Santa Monica Fault Zone at Brockton Avenue Elementary School. The well-defined scarp noted at the Veteran's Hospital and University High School extends farther west and crosses the southern edge of the campus where it was clearly defined and up to 9 meters high before being modified and partly obscured by grading for the southern parking lot. The study consisted of drilling four continuous core borings and 20 CPTs along two different transects perpendicularly across the scarp. Sediments similar in age and lithology to those encountered at University High School were observed in the core samples collected by the consultants.

In their two transects, the consultants identify two subparallel faults, striking approximately N75°E, which they identify as the main trace of the Santa Monica Fault. These faults exhibit about 10 meters of south-side-down apparent total vertical offset in the Pleistocene sediments and correspond closely to the location of the scarp at the campus. They indicate these faults represent the northern limit of faulting consistent with University High School, but state "[t]he southern limit of faulting is located to the southeast of the Brockton Avenue Elementary School campus." Based on this and the data collected at University High School and the Veteran's Hospital to the east, the consultants conclude the faults identified at the site are active and "capable of causing surface rupture."

Locality 5 - 1301-1317 Brockton Avenue

Geotechnologies, Inc. (2005) conducted a geotechnical investigation for a property south of the intersection of Brockton and Texas Avenues in Los Angeles (see Figure 11 – locality 5). There was no fault study *per se* conducted for this site, but a groundwater elevation anomaly was noted by the consultants in their borings drilled across the site from north to south. They indicate this elevation difference likely represents discontinuous perched groundwater bodies within the alluvium. However, groundwater anomalies are associated with the Santa Monica Fault at both University High School (Locality 3) and Brockton Avenue Elementary School (Locality 4) to the east, and therefore, may suggest the presence of faulting in the subsurface at this site also.

Locality 6 - 11954 Santa Monica Boulevard

Beginning in 1988, a soil and groundwater remediation program was initiated at a gas station located at 11954 Santa Monica Boulevard (Figure 11 – locality 6). As part of this mitigation effort, several groundwater monitoring wells were installed at the site to document groundwater elevation and gradient, and to allow for water sample collection and testing. The consultants note a distinct stratigraphic discontinuity between the monitoring well installed in the northwestern corner of the property and the wells across the rest of the site (Delta Consultants, 2010). Additionally, groundwater elevation data collected from the seven wells installed throughout the

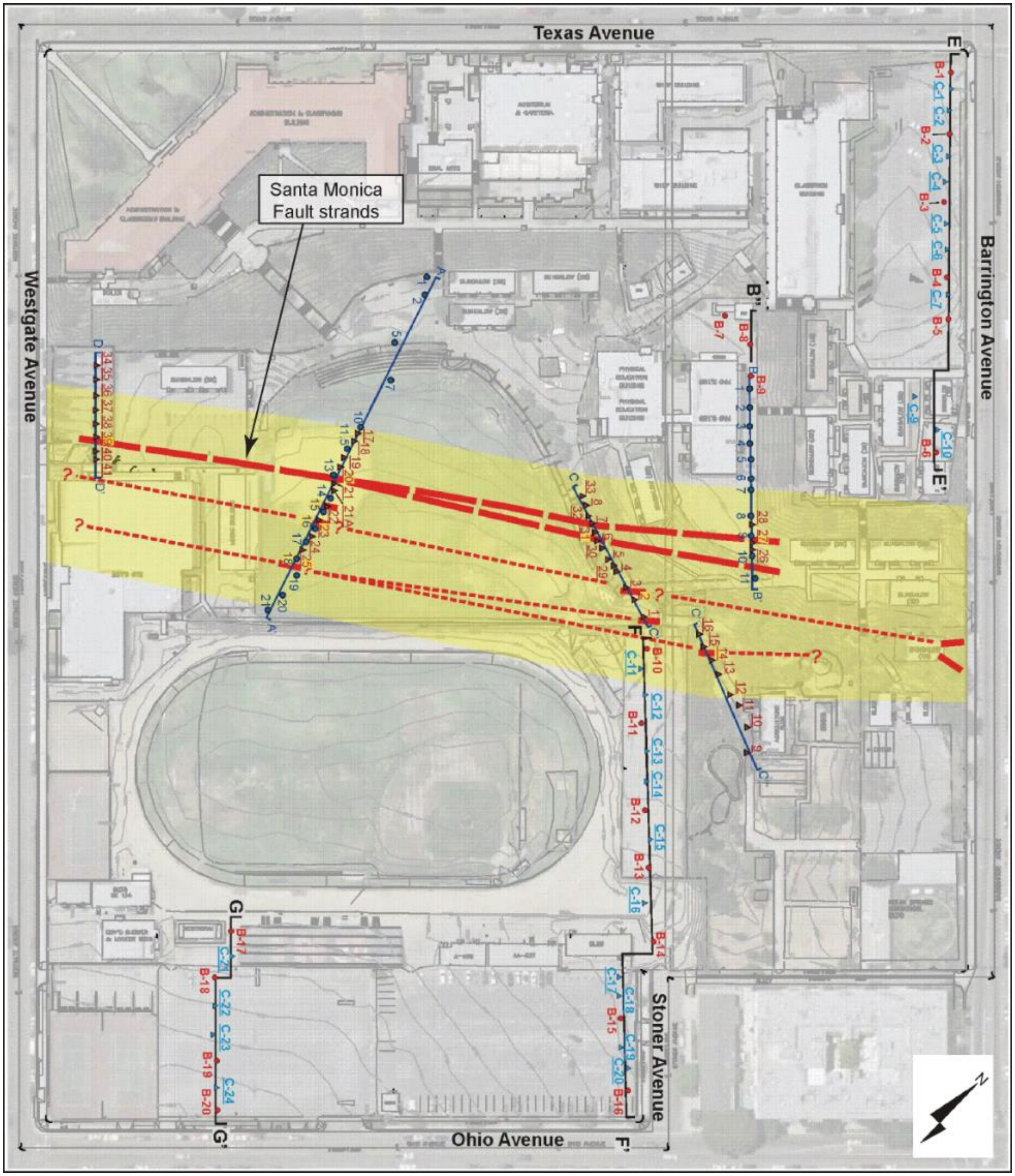

Figure 12 - Map showing interpreted Santa Monica Fault Zone strands crossing the University High School (MACTEC, 2004a & 2007). Red dashed lines are near-surface faults, red dotted lines represent deeper faults projected to the surface. Thin black and blue lines are geologic profiles. Circles are continuous core borings, triangles are CPT soundings. (modified from MACTEC, 2007, Figure 2)

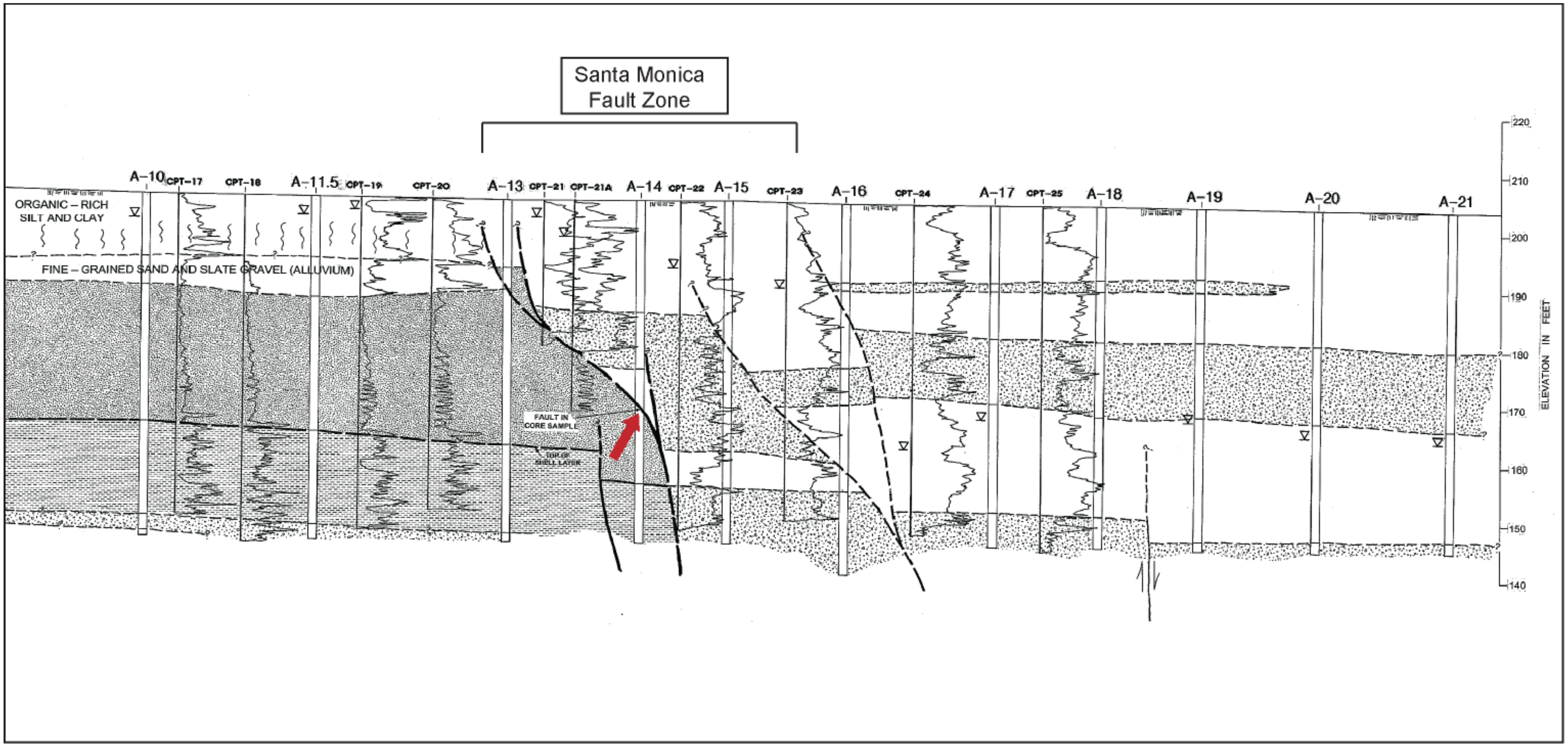

Figure 13 - Portion of geologic cross section A-A' from MACTEC (2004a) at University High School showing discontinuous and offset stratigraphic units and interpreted faults. Red arrow pointing to location where fault zone was observed in the recovered core sample. See Figure 12 for profile location. (modified from MACTEC, 2004a, Figure 5.1)

property indicate a significant groundwater barrier underlies the site in the same area. Groundwater elevations in the northwestern corner are approximately 40 feet deeper than those in the rest of the site. Based on the subsurface data, Delta Consultants stated "it appears that a fault, which truncates the upper water-bearing unit, may be present across the western portion of the site."

Locality 7 - 1522-1528 S. Armacost Avenue

Applied Earth Sciences (2014a) (Figure 11 – locality 7) performed a fault investigation by constructing a linear profile consisting of two continuous core borings drilled to approximately 90 feet deep and nine CPTs advanced to a maximum depth of 91 feet. The borings and CPTs were drilled along Armacost Avenue within one of the "fold scarps" identified by Dolan *et al*. (2000a). Both Holocene and Pleistocene alluvium was encountered and the consultants identified four distinct depositional units within these sediments, which dipped to the south roughly parallel to the existing ground surface. These layers were continuous and unbroken along the entire length of the transect. Additionally, they observed there were no notable breaks in slope or scarps near the site that might suggest the presence of faulting. Consequently, they conclude there are no strands of the Santa Monica Fault Zone at this location.

Locality 8 - 11800-11842 Santa Monica Boulevard

Geocon West, Inc. (2014a, 2015, Figure 11, locality 8) conducted a fault investigation along Westgate Avenue for a proposed mixed-use development. The site is located at the eastern end of a "fold scarp" identified by Dolan *et al*. (2000a) that the authors postulate is formed by near-surface faulting within the Santa Monica Fault Zone. The subsurface investigation consisted of a linear transect of 10 continuous core borings drilled to depths ranging from 65 to 75 feet along Westgate Avenue, which runs essentially perpendicular to the mapped trace of the SMFZ. Geocon West, Inc. reviewed the recovered core samples and identified two distinct alluvial units: Holocene young alluvial deposits and Late Pleistocene older fan/terrace deposits. Three buried argillic soils were identified within the Pleistocene deposits, and the overall sedimentary package dips shallowly to the south. The upper Pleistocene and Holocene sediments were continuous and unbroken across the length of the boring transect. The youngest of these (Marker Bed 1) was determined to range in age from 18,000 to 45,000 years old, and the oldest (Marker Bed 3) is approximately 52,000 to 108,000 years old. Below these soil marker horizons, the consultants interpreted at least three faults were present, which offset older stratigraphic horizons, but not the upper three Pleistocene marker beds. Therefore, they conclude these faults are not active based on the minimum estimated age of Marker Bed 3.

Locality 9 – LA Metro Westside Subway Extension

A large-scale preliminary investigation of the Santa Monica Fault zone was conducted in the Century City area of west Los Angeles (Figure 14 – locality 9) as part of the Westside Purple Line Extension Project (Parsons Brinckerhoff, 2011). Two potential tunnel alignments through this area were approved by the Metro Board in 2010, both of which cross the Santa Monica Fault zone and a postulated fault zone associated with the West Beverly Hills Lineament (WBHL). As a result, a fault investigation was conducted "to determine the location of active faults in the vicinity of the Century City station options and tunnel alignments." Supplemental fault investigations were later conducted east of Beverly Hills High School (Metro, 2017a) and west of the Los Angeles Country Club (Metro, 2017b).

Geomorphically, Parsons Brinckerhoff note the prominent south-facing fault scarp observed at University High School and the VA Hospital to the west, continues east along the north side of Santa Monica Boulevard within the study area. This significant regional scarp provides strong evidence for the main Santa Monica Fault location. The consultants note the

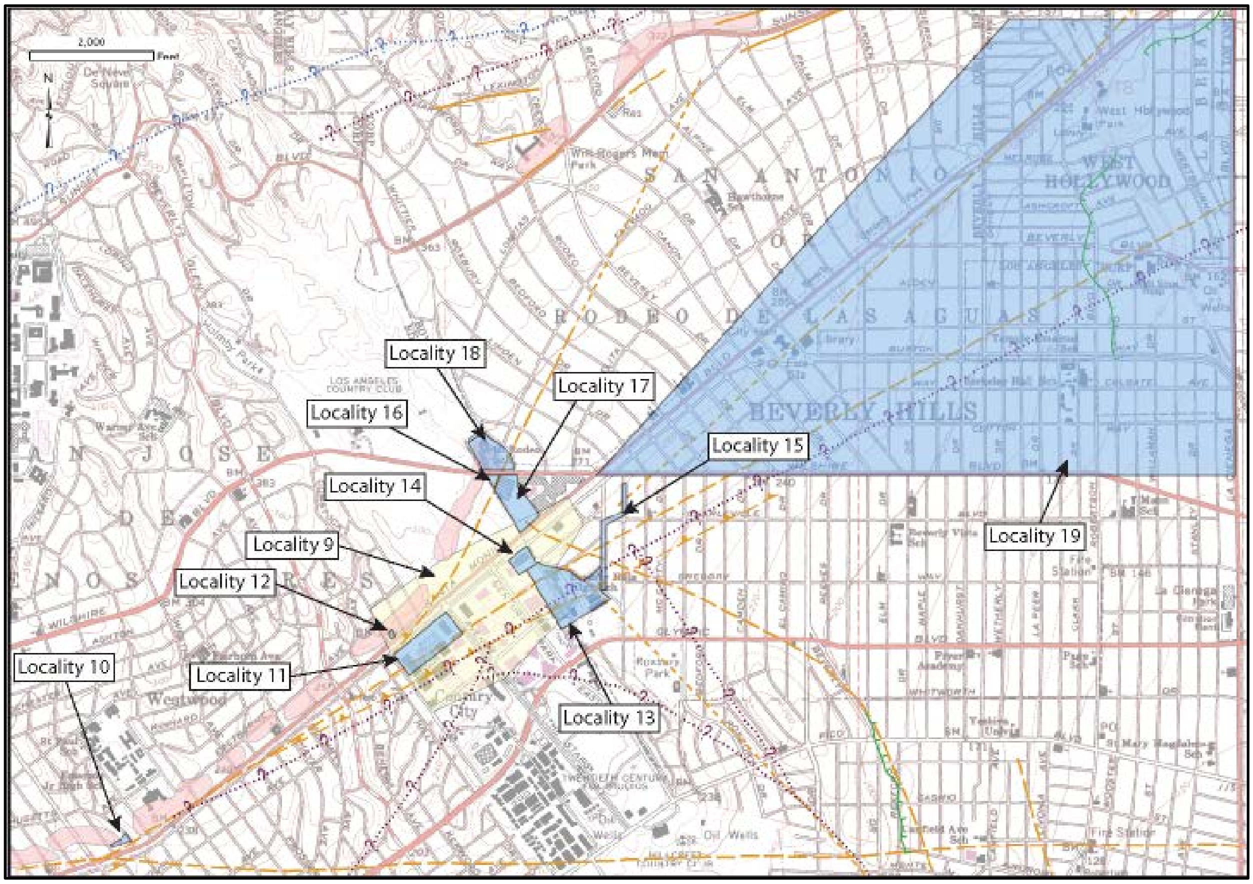

Figure 14 - Study site boundaries (blue shaded area) where investigations provide data relevant to evaluation of the Santa Monica Fault Zone east of Interstate 405 (localities 9 through 19, discussed in text). Light yellow box (Locality 9) is the approximate areal extent of the LA Metro fault investigation. See explanation on Plate 1 for faults types and mapping sources. Light red shaded area is the approximate limit of "fold scarps" identified by Dolan *et al*. (2000b).

easternmost portion of this scarp deviates to a more northeasterly trend at the Los Angeles Country Club, east of Club View Drive, where it continues through the country club and ends at the WBHL near the intersection of Wilshire and Santa Monica Boulevards. However, they indicate this section of the fault scarp appears modified by erosion and the causative faults may lie at some distance to the southeast.

The other robust geomorphic feature within the study area is the WBHL (Plate 2). This topographic element parallels Benedict Canyon Wash and forms a north-northwest-trending series of scarps with uplifted highly-dissected Pleistocene sediments to the west and more flat-lying Holocene to late Pleistocene alluvial plain sediments to the east. The consultants state the origin of this feature has been somewhat enigmatic since being identified by Dolan and Sieh (1992). Various tectonic and non-tectonic explanations have been offered to explain it, but it was never directly investigated in the subsurface until this study.

The investigation consisted of drilling 56 continuous core borings and advancing 192 CPTs along seven transects. Additionally, five seismic reflection profiles were performed along the same transects. Two of these transects crossed the Santa Monica fault scarp and two others crossed the WBHL. From the samples collected, several stratigraphic units were identified

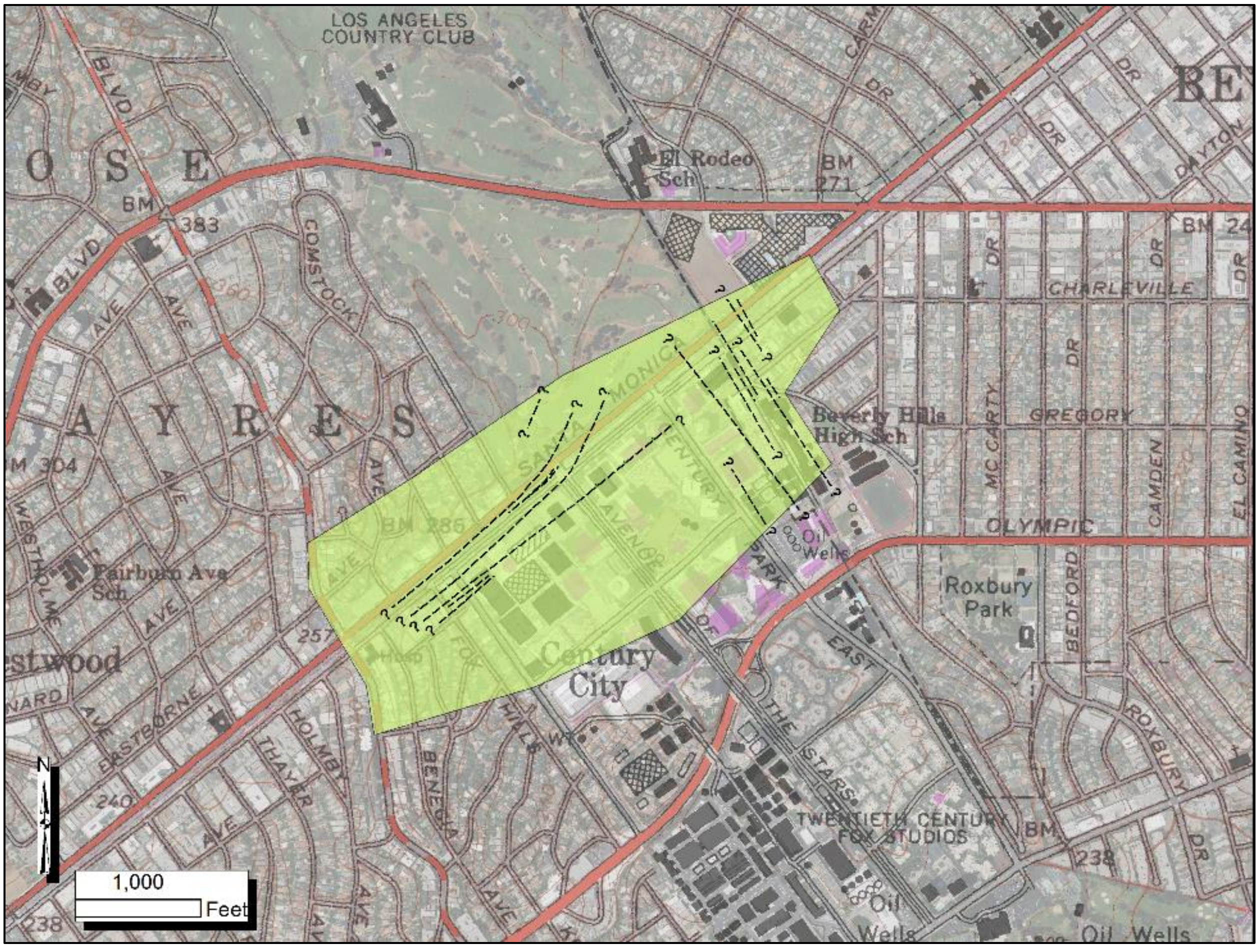

Figure 15 - - Map showing extent of fault investigation for the Century City segment of the Los Angeles Metro subway extension. Dashed black lines are faults interpreted by Parsons Brinckerhoff (2011).

ranging in age from Holocene to middle Pleistocene. The Holocene deposits consist mainly of alluvial fan and stream deposits. Within the older units, late Pleistocene alluvial fan, fluvial, and estuarine sediments are underlain by late Pleistocene non-marine Lakewood Formation and middle Pleistocene marine San Pedro Formation bedrock. It is not clear how the consultants determined the relative ages of the various deposits, as it appears no specific soil development analysis or radiometric dating was performed on the samples collected.

A zone of generally northeast-trending faults associated with the Santa Monica Fault Zone were identified by the consultants paralleling Santa Monica Boulevard (Figure 15). These faults were inferred by noting the locations of "strong discontinuities" between adjacent CPTs, as well as lithologic changes and offset of marker beds observed between core borings along the transects. Additionally, they note these interpreted fault locations coincide with faults interpreted in the seismic reflection profiles and significant drops in groundwater level elevation observed in their borings. However, it could not be determined whether these faults were active because no Holocene units were encountered along these transects. Consequently, only those faults that coincided spatially with the geomorphic scarp were classified as "active".

Two new boring and CPT transects were later constructed west of the Los Angeles Country Club (Metro, 2017b). These transects extend from south to north across Santa Monica Boulevard and were intended to intersect the faults along Santa Monica Boulevard inferred from the Transect 1, 3 and 7 data collected in the initial fault study (Parsons Brinckerhoff, 2011). The investigation consisted of a total of 20 continuous core borings and 45 CPTs divided up between the two transects, with P-wave and S-wave seismic refraction lines also being performed along both lines. Stratigraphic discontinuities, like abrupt thickening of the alluvial deposits and down-dropping of the San Pedro Formation bedrock suggested the existence of a significant fault zone, which is on trend with the fault zone previously identified by Parsons Brinckerhoff (2011) along Santa Monica Boulevard. Based on the findings from the borings and CPTs, as well as the geophysical profiles, the fault zone is interpreted to be a flower structure consisting of an approximately 150-meter wide zone of faulting at the surface, which converges with depth. The largest amount of apparent vertical separation appears to be focused on the southern margin of the zone. Based on documented Holocene activity of faults in this zone to the west at the VA Hospital (Dolan *et al*., 2000a) and at Transect 9 (Locality 15; Metro, 2017a), the investigators consider this fault zone to be active.

Along the WBHL, a northerly-trending zone of faults was identified using the same methodology (Figure 15). Additionally, seismic reflection data and the stratigraphic correlations on Transects 2/2E and 4 suggest the sediments east of this fault zone are folded. Altogether, the consultants conclude these data indicate "a north-northwest-trending zone of late-Quaternary faulting and folding along the WBHL", which is up to 170 meters wide. East of the WBHL, Holocene sediments appear to be either relatively thin or difficult to differentiate from older Pleistocene deposits in the core samples, often being labeled "Younger/Older Alluvial Fan Deposits". Again, this makes it difficult to determine the most recent age of faulting. In the end, the consultants assume this fault zone is the northernmost extension of the active Newport-Inglewood Fault Zone, and as such they state these faults "must be considered" active.

Locality 10 - 1749-1751 Malcolm Avenue

A combined fault study and geotechnical investigation was performed for a proposed residential development at 1749-1751 Malcolm and 1772 Glendon Avenues by Applied Earth Sciences (2015a,b). The fault investigation consisted of a single transect along Malcolm Avenue constructed from 20 CPTs and three continuous core borings drilled to a maximum depth of about 80 feet. Spacing of CPTs/borings varied from 5 feet (between CPT/boring pairs) to over 25 feet in the public right-of-way, where numerous utilities were located. In their borings, the consultants identified both Holocene alluvium and "sag pond" deposits, along with Pleistocene alluvial and estuarine sediments.

No well-developed paleosols were identified in the core samples, thus the consultants used various gravel and silt layers to correlate between CPTs/borings and look for stratigraphic anomalies that would suggest faulting. Their analysis indicated a thick sequence of Holocene silt and clay (interpreted as "sag pond deposits) was juxtaposed against the older Pleistocene sedimentary package between CPT-18 and CPT-19 (Figure 16). Additionally, they note groundwater was encountered in one boring north of CPT-18 and not in either of the borings down gradient to the south. Based on these findings, they interpret an active strand of the Santa Monica Fault trends through the immediate vicinity of CPT-18 and CPT-19. Consequently, the consultants established a "no build zone".

Locality 11 - Westfield Century City Mall

Geocon West, Inc. (2013, Figure 14 – locality 11) constructed two parallel boring transects across a mapped trace of the Santa Monica Fault from the Parsons Brinckerhoff (2011) study that was labeled "Holocene Activity Undetermined". For these transects they drilled 15 new continuous core borings and utilized the data from some of the previously drilled borings and CPTs from Parsons Brinckerhoff (2011). The transects from this study were constructed along

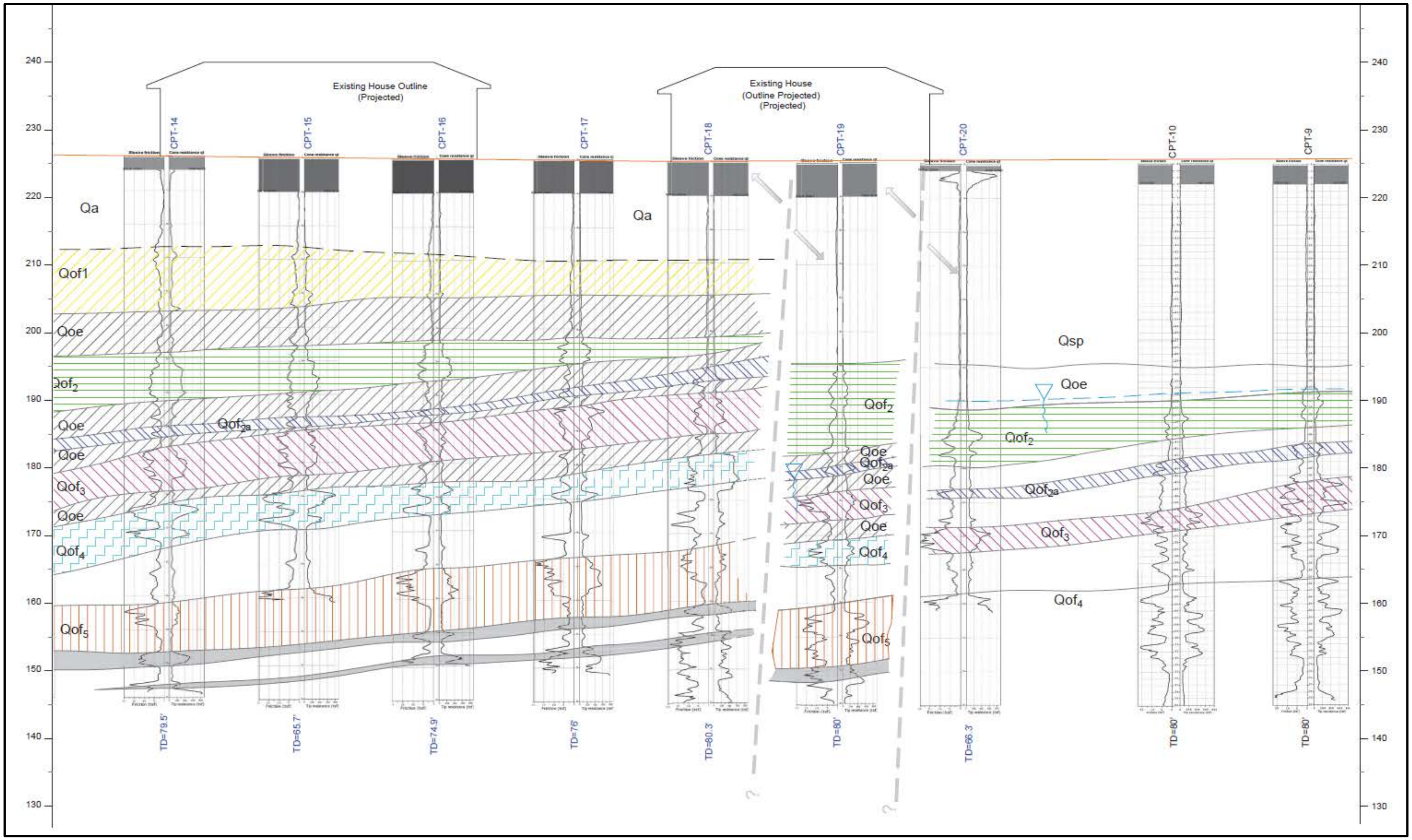

Figure 16 - Portion of geologic cross section A-A' constructed along Malcolm Avenue by AES (2015b, Drawing 2) looking west. Note the thick sequence of Holocene "sag pond" deposits (Qsp) faulted against broadly folded Pleistocene older fan (Qof) and older estuarine (Qoe) deposits in apparent north-side-down vertical separation.

two of the boring-CPT transects from the Parsons Brinckerhoff (2011) study. Geologic units similar in age and depositional environment to those described by Parsons Brinckerhoff (2011), were encountered by the consultants in their borings.

Based on their observations and interpretations of the subsurface data, the consultants identified a northeast-trending fault zone beneath the existing Westfield Mall property consisting of up to five strands, which are vertical or dip steeply to the north. Most of these faults exhibited north-side-down dip-slip motion with one, Fault A, showing south-side down displacement. None of the faults in the zone appear to offset a continuous argillic soil unit estimated to be between 34,000 and 58,000 years old based on soil development analysis.

Locality 12 - 10269 Santa Monica Boulevard

Applied Earth Sciences (AES, 2014b, Figure 14 – locality 12) conducted a fault study for a planned residential building along Santa Monica Boulevard. The subject site is immediately north of two strands of the Santa Monica Fault Zone mapped by Parsons Brinckerhoff (2011) within Santa Monica Boulevard. They advanced six CPTs, three continuous core borings, and incorporated geotechnical borings previously drilled at the site. Additionally, they incorporated one of the continuous core borings and two of the CPTs from the Parsons Brinckerhoff (2011) study along Warnall Avenue, immediately west of the subject site. AES identified many Holocene alluvium, and both Pleistocene alluvial and estuarine deposits in their borings and used sedimentary layers and unique CPT data signatures to evaluate the continuity of the sediments underlying this site. The consultants constructed a geologic cross section along their primary boring transect and drew two additional cross sections to cross-correlate their subsurface data with the previous boring and CPT data from Parsons Brinckerhoff (2011). In all sections, the consultants identified similar stratigraphic units and marker beds that were continuous across (2011) interpretation that the main strands of the SMFZ are in close proximity to the southern boundary of this site based on the shallowing of groundwater to the south and the presence of a scarp to the south, between the site and Santa Monica Boulevard.

Locality 13 - Beverly Hills High School

A fault investigation was performed for the northern portion of Beverly Hills High School campus (Leighton Consulting, Inc., 2012a,b,c, and 2013) to assess several active faults mapped at the site by Parsons Brinckerhoff (2011) (Figure 14 – locality 13). These mapped faults consisted of north-northwest-trending fault zone associated with the WBHL, which traverses the campus, and a northeast-trending fault related to the Santa Monica Fault, which projects towards the site (Figure 15).

For the fault investigation, the consultants excavated and logged five fault trenches, advanced 12 CPTs, and drilled 26 continuous core borings along three transects. Detailed observations were made of the soil types, textures and colors, as well as any fractures or other discontinuities. The consultants also provided interpretations of depositional environment and estimated ages of the sedimentary deposits and paleosols exposed in the trenches. On several occasions CGS geologists visited the site to observe the fault trenches and review soil core samples collected from the borings.

The consultants identified several paleosols, other marker beds, and the contact with the underlying San Pedro Formation in their core borings, which they trace along the entirety of each transect across the WBHL. Based on soil development in the older alluvium exposed in the trenches and observed in the core samples, the sediments underlying the elevated western surface were estimated to range from a minimum of 70,000 to 100,000 years old. Additionally, observations made in their Fault Trench 2 (FT-2) demonstrate the older alluvial deposits are

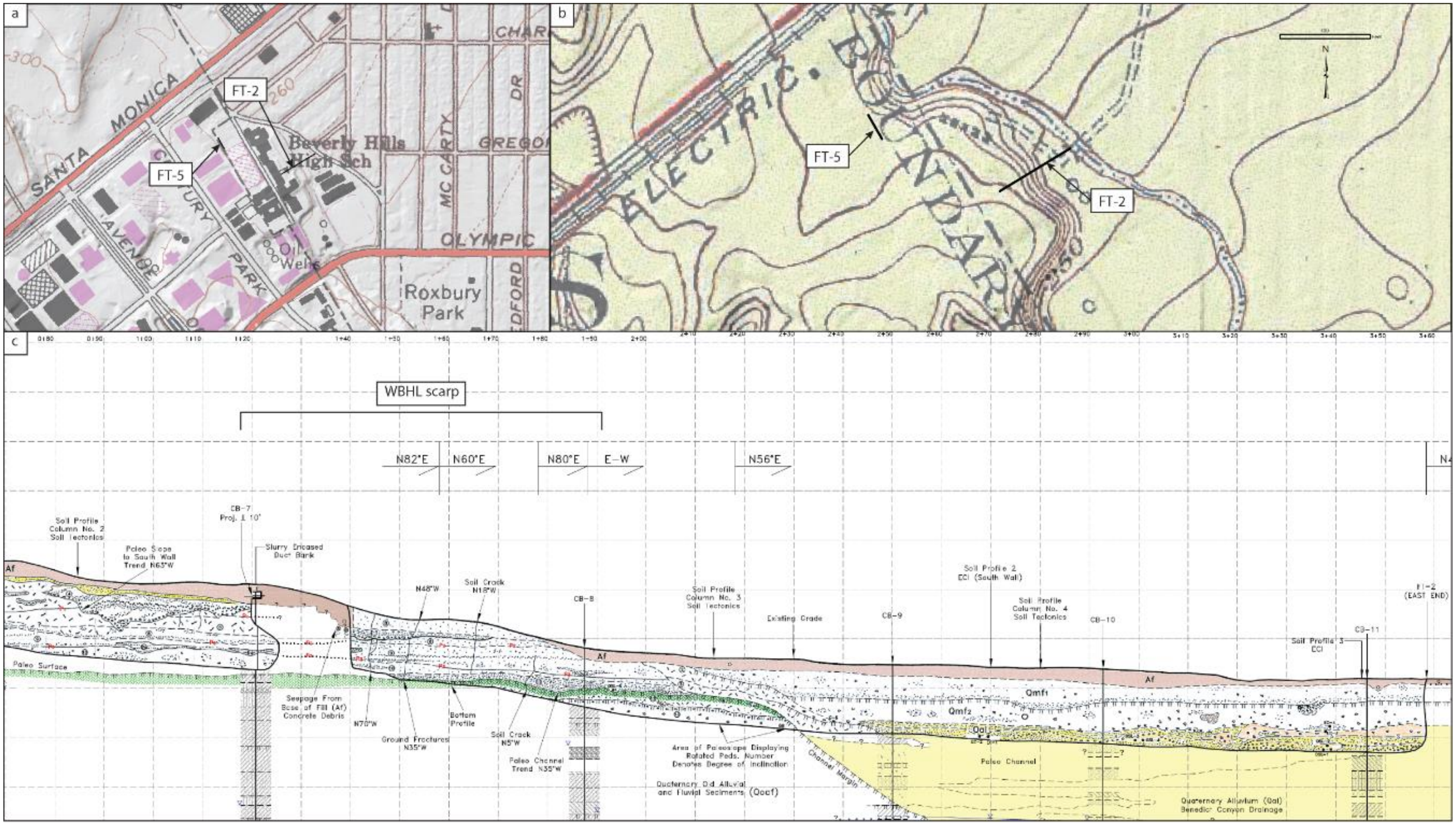

Figure 17 - a) Index map showing location of trenches FT-2 and FT-5 on modern topographic base map. b) Trench locations on 1925-era topographic map showing WBHL scarp prior to modification. c) Portion of geologic cross section and fault trench log for FT-2 at Beverly Hills High School (from Leighton Consulting, Inc., 2012a, Plate 3). Af = artificial fill; Qmf = mud flow deposits (Holocene); Qal = alluvium (Holocene); Qoaf = older alluvial fan deposits (late Pleistocene)

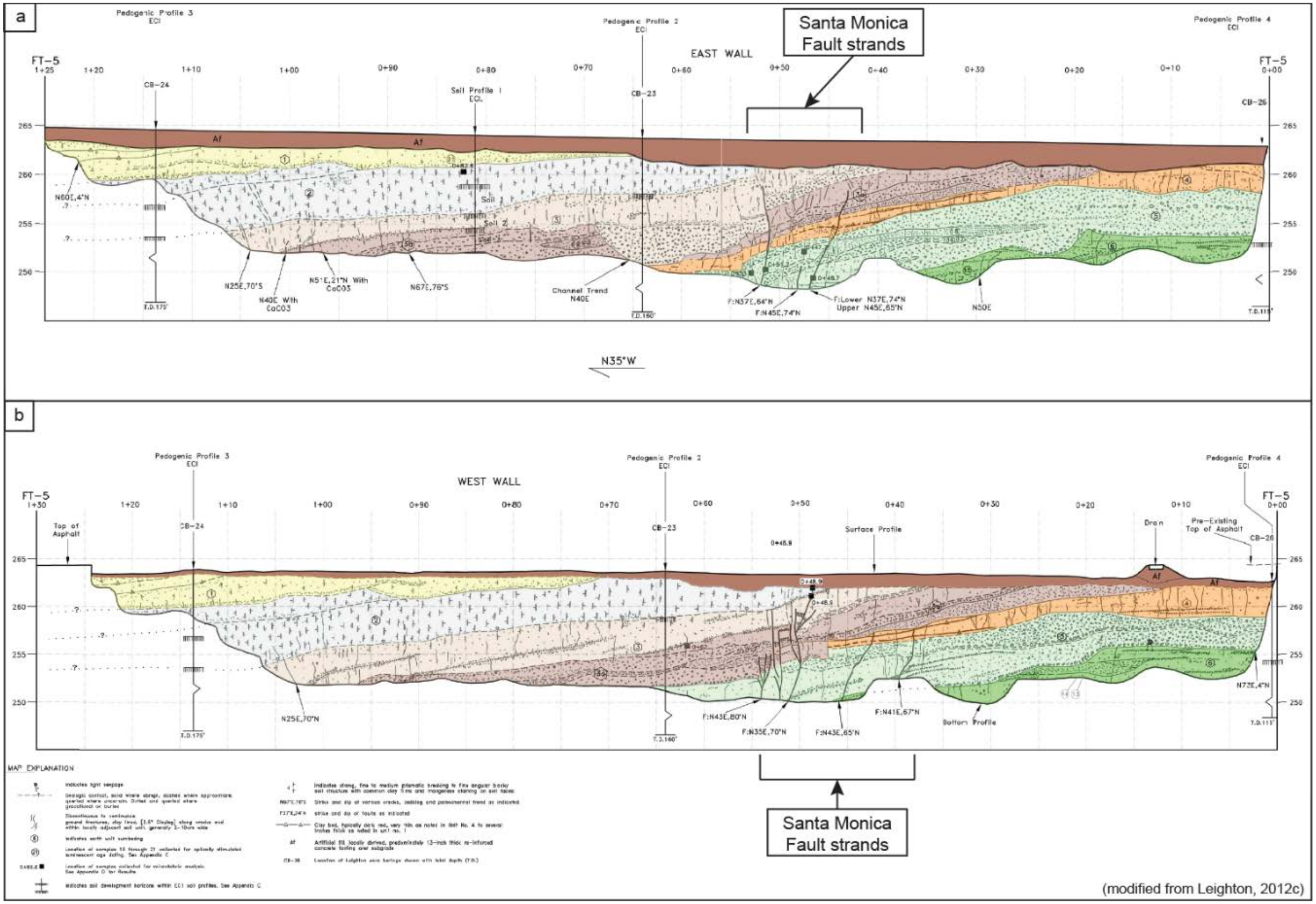

Figure 18 - Log of Fault Trench 5 (FT-5) at Beverly Hills High School depicting (a) east and (b) west walls. Log depicts folded and faulted late Pleistocene units. Leighton (2012c) concluded these fault strands were inactive. (modified from Leighton Consulting, Inc., 2012c, Plate 5)

laterally truncated, which the consultants conclude indicates an erosional origin for this slope (Figure 17). The erosional contact between the older alluvium and the younger alluvium of Benedict Canyon forms a buttress unconformity, which the consultants state can be followed below the trench exposure and observed in their core borings along the transect (Figure 16c). Thus, they conclude there are no active faults along the WBHL as reported by Parsons Brinckerhoff (2011) and the scarp feature appears to be erosional, not tectonic, in nature.

In the northwestern corner of the campus, a northwest-trending boring transect identified an approximately 90-foot drop to the north in the San Pedro bedrock surface near where a trace of the Santa Monica Fault Zone mapped by Parsons Brinckerhoff (2011) would project onto the campus (Leighton Consulting, Inc., 2012c). Consequently, the consultants excavated a fault trench along a portion of the transect and observed faulting within the alluvial sediments near the surface (Figure 18). Based on soil-stratigraphic age estimates, the consultants concluded the youngest sediments exposed in this trench range from approximately 30,000 to 60,000 years old (Unit 1), and the oldest unit was estimated at 143,000 to 335,000 years old (Unit 6). Several faults were exposed in the trench and were described as an "upwardly flowering and stepping zone of faults and fractures about 20 feet wide and having a cumulative ± 3 feet of north side down displacement, and some undetermined lateral offset". Attitudes on the faults ranged from N35°E to N43°E with dips between 65° to 75° north. Detailed logging by the consultants allowed for the interpretation of at least two, and possibly three, distinct rupture events recorded in the trench sediments. The most recently active strand of the fault zone extends up from the bottom of the trench and appears to offset the base of Unit 2. They note the fault is much less clearly defined within Unit 2, which they interpret as being due to a lack of recent movement and progressive destruction of the fault rupture surface by soil development. Consequently, they conclude the most recent event occurred "when Unit 2 was the ground surface but before the development of the strong B_t that caps it, because the fault traces are only readily visible within the C horizon [Unit 3] beneath the B_t." It appears the location of this fault zone is generally consistent with the fault projection mapped by Parsons Brinckerhoff (2011). Because Unit 2 is Pleistocene in age, and the faulting at the base appears to pre-date the argillic B_t horizon, Leighton Consulting, Inc. concluded these faults are not active. However, unlike the alluvial deposits along the WBHL, it does appear the Pleistocene sedimentary sequence north of this fault is notably folded with all units dipping on the order of 10° to the north (Figure 18).

Locality 14 - 10000 Santa Monica Boulevard

Geocon West (2012) excavated a fault trench for a proposed commercial development at 10000 Santa Monica Boulevard, immediately northwest of the Beverly Hills High School (BHHS) campus (Figure 14 – locality 14). The trenching study was conducted to intercept and evaluate two postulated fault strands relating to the WBHL mapped by Parsons Brinckerhoff (2011) across this site. The fault trench was excavated on a northeasterly trend to intercept the postulated faults and was approximately 300 feet long and up to 20 feet deep. A series of layered fining-upward alluvial sequences were exposed in the trench that were all determined to be Pleistocene in age based on soil development age estimates. Based on detailed logging of the trench exposures, no faults were observed offsetting any of the Pleistocene sediments.

Locality 15 - Metro Transect 9

In 2017, AMEC Foster Wheeler performed a supplemental fault investigation for the planned LA Metro Westside Purple Line subway extension (Metro, 2017) to assess a strand of the Santa Monica Fault Zone encountered during the preliminary fault investigation report (Parsons Brinckerhoff, 2011), which trended northeasterly towards a section of the proposed subway alignment. To investigate for potential faulting, a series of continuous core borings and CPTs were drilled along Laskey Drive, turning east at Charleville Boulevard, and continuing north along Spaulding Drive (see Figure 14, locality 15). This was referred to as Transect 9, which continues the numbering sequence from Parsons Brinckerhoff (2011). The new subsurface profile was constructed using data collected from twenty new continuous core borings drilled from 110 to 245 feet deep and 34 CPTs advanced to depths ranging from 61 to 117 feet. Based on the subsurface data the consultants identify Holocene and Pleistocene alluvial units overlying bedrock of the Pleistocene Lakewood and San Pedro Formations.

From their observations and interpretations of the subsurface data, AMEC Foster Wheeler identified a significant fault zone at depth between their stations 6+50 and 9+00 (Figure 19) consisting of up to three strands, which dip steeply to the north. The faults exhibited greater than 90 feet of apparent down-to-the-north vertical displacement of the contact between the older alluvium and the Lakewood Formation. From the southern end of the cross section, the depth to the Pleistocene bedrock units consistently increases to the north until they are abruptly truncated and no longer encountered north of the inferred fault zone. AMEC states these faults appear to extend up near the present-day ground surface and offset Holocene sediments dated between approximately 9,100 and 16,500 years old based on radiometric dating of charcoal samples. The locations of the fault traces in the near surface sediments is based on identifying the location where laterally persistent laminated fine-grained "sag deposits" to the north are abruptly missing in adjacent down-gradient borings. It is postulated these fine-grained silts and clays were deposited in depressions or impounded drainages formed by topographic scarps created by surface-rupturing events along faults in this zone. Additional faults were also interpreted between borings north and south of this main zone.

Locality 16 - 9988 Wilshire Boulevard

In 2005, a groundwater monitoring program was initiated at a gas station located at 9988 Wilshire Boulevard, immediately northwest of the 9900 Wilshire Boulevard project (Figure 14 – locality 16). The groundwater elevation data collected from the nine wells installed throughout the roughly triangular property indicate a significant groundwater barrier underlies the site. Groundwater elevations in the northwestern corner are approximately 25 feet higher than those in the central and southeastern areas of the site (Delta Consultants, 2009; Antea Group, 2015). The consultants for this project state it is possible the two groundwater-bearing zones are separated by a fault beneath the site (Delta Consultants, 2009).

Locality 17 - 9900 Wilshire Boulevard

To the north of the 10000 Santa Monica Boulevard site (Figure 14 – locality 17), is a former department store located at 9900 Wilshire Boulevard. As part of the proposed redevelopment for this property, a fault investigation was conducted at the site by Geocon West, Inc. (2014b). Parsons Brinckerhoff (2011) mapped two postulated faults trending north-south through the southern boundary of the site and several northeast-trending faults, which project towards the site from the adjacent country club to the west.

The investigation by Geocon West, Inc. (2014b) consisted of three fault trenches, as well as nine CPTs and 18 continuous core borings drilled along two transects. Additionally, the consultants reviewed the data and interpretations from two seismic reflection profile surveys performed previously at the site by GeoVision (2012). The two transects were specifically located to intersect mapped faults from the Parsons Brinckerhoff (2011) study and "reasonable projections" of other faults from that study, which projected towards the site. Borings and/or CPTs exploration points along these transects were drilled to approximately 70 feet deep and were spaced on the order of 20 to 40 feet apart. From the trench exposures and the core samples collected from the borings the consultants identified both Holocene and Pleistocene alluvial deposits with soil marker units, which are underlain by the late Pleistocene Lakewood Formation.

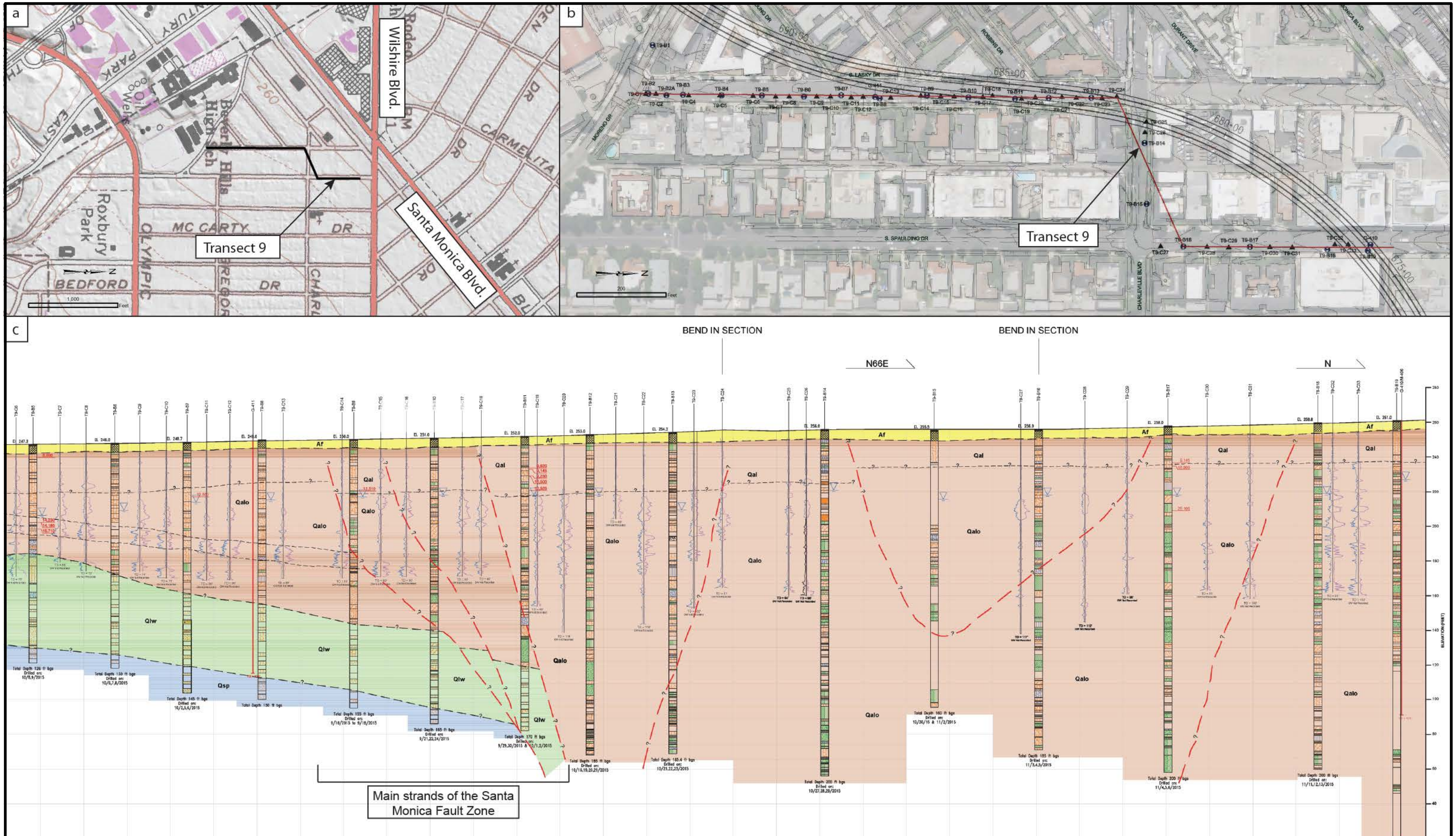

Figure 19 – Location and geologic profile at Locality 15. a) Index map showing location of Transect 9 from Metro (2017a) report. b) aerial photo map depicting locations of borings and CPTs drilled along the transect. c) portion of geologic cross section constructed along Transect 9 by Metro (2017). Af = artificial fill; Qal = alluvium (Holocene); Qalo = older alluvium (late Pleistocene); Qlw = Lakewood Formation (late Pleistocene; non-marine); Qsp = San Pedro Formation [modified from Metro (2017a, Plate 2)]

Soils exposed in the trenches indicate the Holocene soils range from 4,000 to 12,000 years old and the uppermost Pleistocene alluvial fan sediments are approximately 27,000 years old.

The three trenches were excavated across areas of either mapped faults by Parsons Brinckerhoff (2011) or across potential fault features interpreted from the seismic reflection profiles. In all three trenches the consultants observed "continuous unbroken, pre-Holocene sediments", which indicates there is no active faulting at these locations and the faults mapped across these locations do not exist or offset sediments that are older, and therefore, below the bottom of the trench exposures.

One transect was constructed from borings and CPTs drilled along the western margin of the site in line with Trench 1. This alignment was designed to intercept faults mapped by Parsons Brinckerhoff (2011) to the southwest along the base of a geomorphic scarp in the Los Angeles Country Club to the southwest (Figure 15). This scarp is believed to be related to the Santa Monica Fault (Dolan and Sieh, 1992; Dolan *et al*. 2000a). Geocon West, Inc. notes groundwater monitoring well data from a gas station northwest of the site at 9988 Wilshire Boulevard (Figure 14 – locality 16) indicates a groundwater barrier, which roughly aligns with the trend of this geomorphic scarp. Based on their observations and analysis of the subsurface data, the consultants identified five faults (A through E) based on clear offsets in the Lakewood Formation sediments and a marker bed within Pleistocene terrace deposits. These fault designations are different from the lettered faults described by Parsons Brinckerhoff (2011) and KGS (2013, 2014, 2016). They note these faults are widely spaced and may represent a branching of the Santa Monica Fault as it approaches the WBHL area. They conclude, however, these faults are not active as they do not offset the overlying Pleistocene alluvial fan and Holocene alluvium units.

A second boring-CPT transect was drilled in the center median of Wilshire Boulevard, along the northern site boundary. This alignment was intended to intersect any additional faults associated with the northeasterly-trending scarp offsite to the west or any northerly-trending faults potentially associated with the WBHL. As a result of their analysis, five faults were identified that offset stratigraphic marker units. Across one of these faults a significant change in groundwater elevation was also observed. Of the faults identified, three were determined to offset the Holocene alluvial unit, and were therefore, considered active. The consultants interpreted the major sense of offset along these faults to be strike-slip, with some local components of dip slip, both normal and reverse. Additional data related to these faults was collected by Leighton Consultants, Inc. (2015, 2016) and is discussed under Locality 18 below.

Because of the uncertain trend of these active faults, Geocon West, Inc. recommended a 50-foot structural set-back zone along the northwestern boundary between the subject site and the 9988 Wilshire gas station site.

Locality 18 - El Rodeo Elementary School

Leighton Consultants, Inc. (2015, 2016) conducted a fault study for the El Rodeo Elementary School campus in Beverly Hills (Figure 14 – locality 18) since various studies suggested active faulting projected toward the site. Dolan *et al*. (1997, 2000a) noted the prominent northeast-trending scarp at the southern end of the Los Angeles Country Club projects directly towards this campus (Plate 2). They interpreted this scarp as the easternmost extent of the Santa Monica Fault. Additionally, GeoconWest, Inc. (2014b), in their investigation for the 9900 Wilshire Boulevard project (Locality 17), identified three faults under Wilshire Boulevard that they concluded were active and trended toward the campus based on their alignment with the country club scarp and the adjacent groundwater barrier at 9988 Wilshire Boulevard (Locality 16).

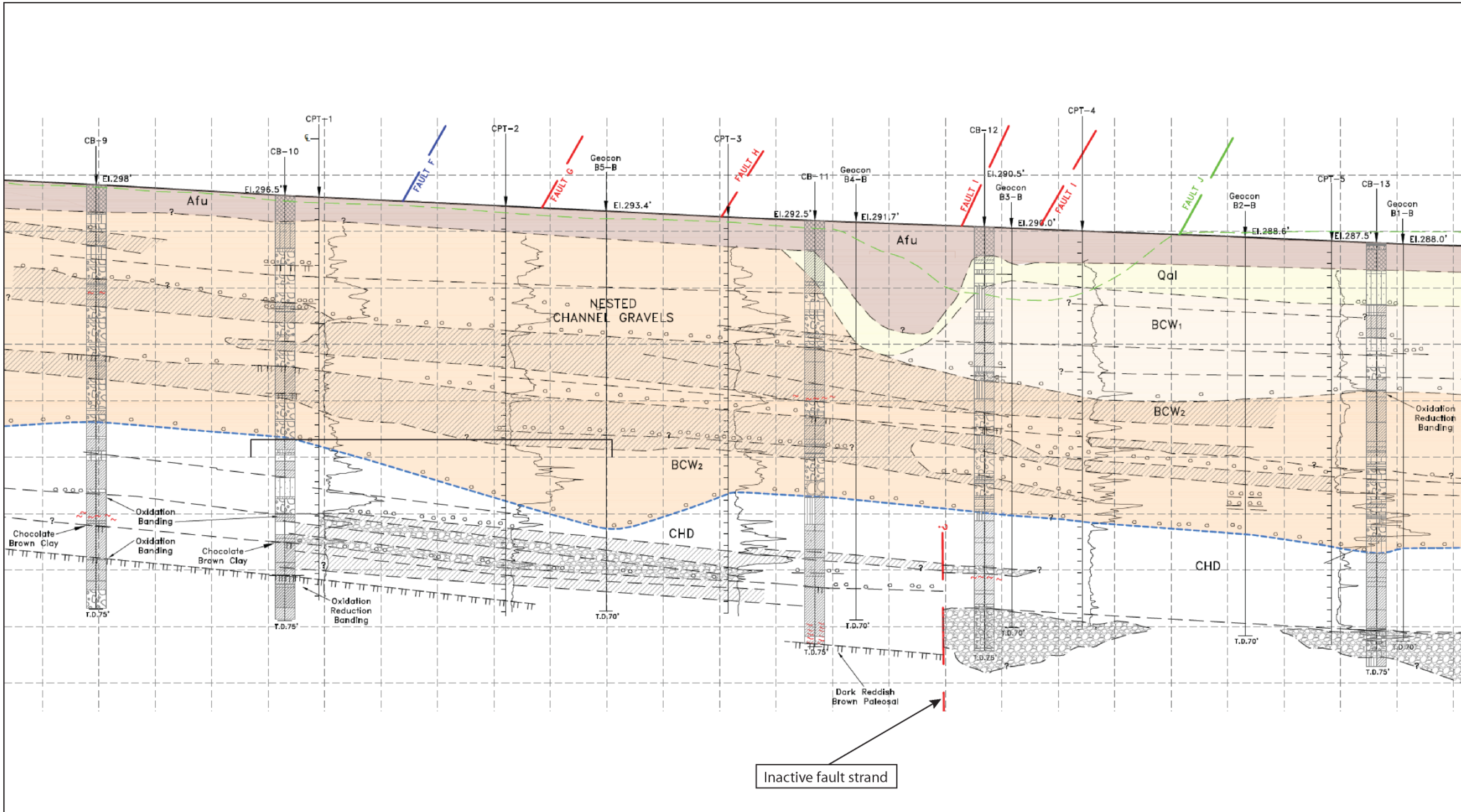

Figure 20 - Portion of geologic cross section along Wilshire Blvd., south of El Rodeo Elementary School. Colored fault labels along top of profile note inferred locations of faults by Geocon West (2014b). Afu = undocumented artificial fill; Qal = Quaternary alluvium (Holocene); BCW = Benedict Canyon Wash Deposits (late Pleistocene); CHD = Cheviot Hills Deposits (late Pleistocene) [from Leighton Consulting, Inc., 2016, Plate 3]

For the fault investigation, Leighton Consulting, Inc. excavated and geologically logged five fault trenches and drilled 23 continuous core borings along or adjacent to Wilshire Boulevard. The boring transect along Wilshire Boulevard followed the same line as that from the 9900 Wilshire Boulevard fault study (Geocon West, Inc., 2014b) (Locality 17), and incorporated the previous boring and CPT data from that study. The additional borings drilled by Leighton Consultants, Inc. provided increased resolution by minimizing the distance over which stratigraphic correlations were made and they allowed for additional soil sampling and dating analysis. Detailed observations were made of the soil types, textures, and colors, as well as any fractures or other discontinuities. The consultants also provided interpretations of depositional environment and estimated ages of the sedimentary deposits and paleosols exposed in the trenches using the Quaternary stratigraphic framework established by KGS (2014). On several occasions CGS geologists visited the site to observe the fault trenches and review soil core samples collected from the borings.

Leighton Consulting, Inc. identified several paleosols, other marker beds, and major erosional surfaces, which they trace along the entirety of the transect across the trace of the projected faults (Figure 20). Based on logging of the soil cores and sediments, as well as the various degrees of soil development exposed in the trenches and observed in the core samples, the consultants determined that the elevated western portion of the campus is underlain by Older Benedict Canyon Wash Deposits ($BCWD_2$), which are folded into an east-dipping monocline. The lower, eastern portion of the school site is underlain by the younger $BCWD_1$ deposits that onlap the $BCWD_2$ from the east creating a buttress unconformity. This depositional model explained several apparent stratigraphic discontinuities that were initially thought to be fault related by Geocon West, Inc. (2014b) who assumed all strata in this area to be horizontal. Some faults were inferred at depth in the transect, but they were overlain by apparently continuous and unbroken Pleistocene sediments and paleosols (Figure 20). No evidence of faulting was observed within the Pleistocene alluvial soils exposed in any of the trenches excavated across the projected Geocon or Leighton Consultants fault traces. Thus, they concluded there are no active faults at the site.

Locality 19 – Beverly Hills groundwater data

Petra Geosciences provided CGS with both historical groundwater elevation data and topographic survey data they collected and evaluated as part of a site investigation in downtown Beverly Hills (M. Schultz, pers. comm., 2014). The purpose of their study was to screen the area for potential shallow subsurface faulting. The groundwater data collected was from various sources, including geotechnical borings and monitoring wells drilled in the area, and resulted in identifying various local groundwater barriers, which are subparallel to the trend of the SMFZ. One of these barriers was interpreted from a 30-foot drop in groundwater elevation across a horizontal distance of approximately 250 feet (Figure 21). Additionally, Petra collected topographic survey data of various benchmarks collected by the City of Los Angeles between 1985 and 2000. Changes in the measured benchmark elevations over the time allowed for the identification of a zone of differential subsidence shown in Figure 21. These areas showed a noticeably higher settlement rate compared to other portions of the study area, which might suggest the presence of faulting in the shallow subsurface. No faults were specifically interpreted from this data, but the noted groundwater barriers and subsidence zone roughly aligns with the northern strand of the SMFZ observed in Transect 9 at Locality 15 (Metro, 2017a).

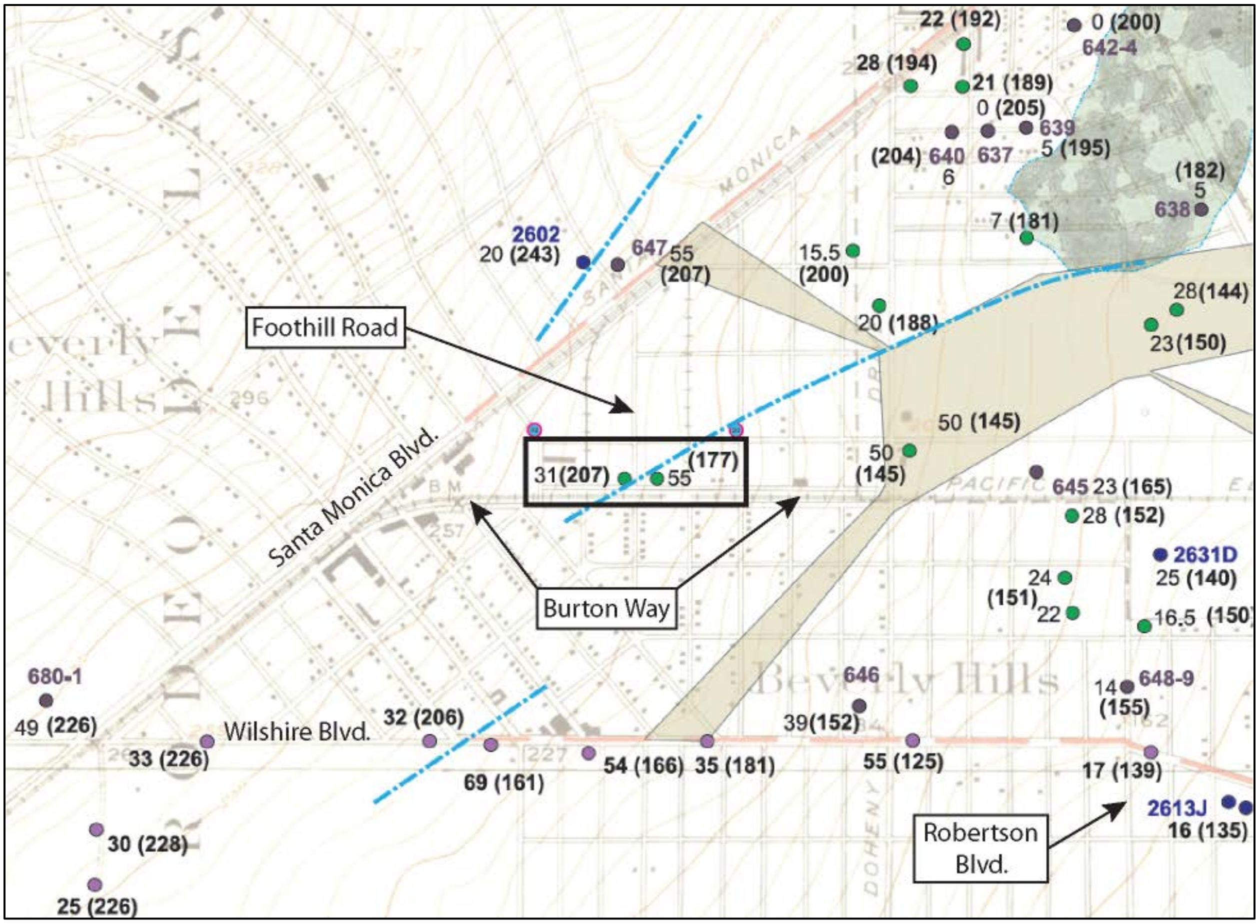

Figure 21 – Map depicting groundwater well data and differential subsidence zones in the western Beverly Hills alluvial plain. Colored dots represent locations of borings/wells with groundwater elevation in parentheses. Dashed blue lines are interpreted groundwater barriers by M. Schultz. Tan shaded area is the zone of differential subsidence based on City of Los Angeles benchmark elevation surveys conducted between 1985 and 2000. Variegated shaded area is the limits of a historical marsh reported by Mendenhall (1905). (modified from map provided by M. Schultz, pers. comm., 2014)

SUMMARY OF AVAILABLE DATA FOR THE HOLLYWOOD FAULT

LITERATURE REVIEW

The Hollywood Fault was previously mapped by many workers including Hoots (1931), Hill *et al*. (1979a,b), Dibblee (1991), and Yerkes (1997). These workers all show the fault at the steep break in slope along the southern edge of the Santa Monica Mountains, although each mapper varies in how far west they extend the fault from the quadrangle boundary (Plate 1). In early studies of the tectonics of the northern Los Angeles Basin, this fault zone was referred to as the Santa Monica Fault and was believed to extend from Santa Monica Bay to the Los Angeles River, where it was thought to connect in some manner to the Raymond Fault, identified to the east in Pasadena. More recent geomorphic interpretations by Dolan *et al.* (1997, 2000b) and Kenney GeoScience (KGS, 2014, 2016), as well as site-specific subsurface data by private geotechnical consultants (discussed later in this report), provide a more detailed view of the fault location and geometry.

Initially thought to be a predominantly reverse fault, recent subsurface investigations along the Hollywood Fault to the east in the Hollywood quadrangle (Dolan *et al*.: 1997, 2000b; Law/Crandall, 2001; William Lettis and Associates, 2004) suggest there is a significant component of left-lateral strike-slip. Meigs and Oskin (2002) measure up to 2.9 km of cumulative oblique-slip offset along the Hollywood Fault since about 5 Ma and calculate a minimum slip rate of approximately 0.5 mm/year. They also state the "dip-slip motion on the western Hollywood Fault has been accompanied by folding of the hanging wall". Cooke and Marshall (2006) report a net slip rate of approximately 1.0 mm/year.

Using newer data, which included geologic mapping and subsurface data reported by Dolan *et al.* (1997, 2000b) and various geotechnical investigations, the Hollywood Fault was re-evaluated within the Hollywood Quadrangle by Hernandez and Treiman (2014) and an Alquist-Priolo Earthquake Fault Zone was established for the Hollywood Fault.

Hill *et al*. (1978, 1979a, 1979b)

Hill and others (1978, 1979a, 1979b) reviewed available surficial geologic data, as well as oil well, gravity, groundwater, and historic precision leveling survey data to evaluate the location and activity of the Hollywood Fault. Based on these data, they postulated the Hollywood Fault extends west of Benedict Canyon to connect with the Potrero Canyon Fault exposed in the cliffs at Pacific Palisades. This interpretation was based on locally evident geomorphic scarps in the Pleistocene alluvial fan surfaces and deep oil well data; however, they admitted this connection and the continuity of the Hollywood Fault north of Santa Monica is uncertain.

Crook *et al*. (1983) and Crook & Proctor (1992)

Early work by Crook *et al.* (1983) and Crook and Proctor (1992) summarized previously unpublished geologic data collected from various localities along the Hollywood Fault. Two of the reported sites are within the study area. These are Greystone Park and the Southern Regional Library at UCLA (Plate 1). The authors logged portions of a roadcut at Greystone Park that exposes Jurassic Santa Monica Slate in contact with a sedimentary unit consisting of massive pebbly arkosic sand. They state the nature of the contact was difficult to determine but it has "the general appearance of being depositional." However, they also observed two shear surfaces within the slate that dipped 72° and 75° north. They state the age of the sedimentary unit is unknown, but may be as old as Tertiary based on degree of weathering and soil development. Elsewhere on the park property, several oil and water seeps were noted that appear to align with the shears documented in the road cut. Therefore, the authors conclude "it thus appears the Hollywood fault passes through the Greystone Park property.

The second site is on the campus of UCLA. Crook and Proctor (1992) report a fault placing Miocene age Modelo Formation shale over Pleistocene alluvium was observed in an excavation for the Southern Regional Library (Plate 1). The fault strikes N60°E and dips about 35° north. Based on the measured strike it appears this fault lines up with a small fault mapped by Hoots (1931) to the northeast. Lastly, the consultants excavated a long north-south-trending trench on the Veteran's Administration Hospital site to the southwest, hoping to intercept the fault, but no faulting was observed.

Dolan *et al*. (1997) and Dolan *et al*. (2000b)

Dolan *et al*. (1997) performed site-specific subsurface fault investigations, coupled with geomorphologic mapping performed by Dolan and Sieh (1992), to evaluate the paleoseismology and seismic hazards associated with the Hollywood Fault. The authors note "…linear scarps and faceted south-facing ridges confirm that recent activity on the Hollywood fault is concentrated along the southern edge of the Hollywood Hills in Hollywood and Beverly Hills" (Dolan *et al*., 1997). Additionally, they state the presence of active alluvial fan deposition along the mountain front, without significant fan incision, suggests rapid and recent uplift of the Santa Monica Mountains between Beverly Hills and the Los Angeles River. In the West Hollywood and northern Beverly Hills areas, Dolan *et al*. (1997) observed the fault may bifurcate into two main strands. They comment the northern strand is weakly defined by an alignment of discontinuous scarps, especially west of Benedict Canyon, and may represent an older westward extension of the Hollywood Fault. The southern strand forms a more prominent scarp in the alluvial fan surface several meters south of Sunset Boulevard and diminishes to the west towards Doheny Drive, although they note "differential stream incision of the alluvial apron ~850 m west of Doheny Drive suggests recent warping and possible faulting of the fan surface." South of Sunset Boulevard, the alluvial fan surfaces slope up to 17°, which is too steep to be wholly depositional, further suggesting recent tectonism along the mountain front. Fault trenches and boring transects near downtown Hollywood, east of the Beverly Hills quadrangle, located several splays of the fault and the authors state the most recent earthquake event on the Hollywood Fault was likely 7 ka to 9.5 ka, with a penultimate event between 10 ka and 22 ka (Dolan *et al*., 2000b). From this investigation, the authors concluded "… the Hollywood fault is active, having produced an early to mid-Holocene event that was large enough to rupture the surface."

PALEOSEISMIC STUDIES AND CONSULTING REPORTS

(for referenced localities, see Figure 22)

Critical studies that bear on the location and recency of faulting along the western Hollywood Fault chiefly rely on geologic and geotechnical studies within the City of West Hollywood.

The City of West Hollywood's Fault Precaution Zone Map, and Geologic and Seismic Hazard Technical Background Report (KFM Geoscience, 2010) is a crucial component of the City of West Hollywood General Plan. Included in the KFM report is a summary of Fault Rupture Hazard Studies from 29 sites that are on file with the City, collected from 1997 to 2013. Of these reports, eight sites yielded data that active faulting exists within those sites or otherwise helped constrain the fault location near the eastern boundary of the Beverly Hills Quadrangle. Of these eight sites, several studies were performed adjacent or in close proximity to one another; these are shown on Figure 22.

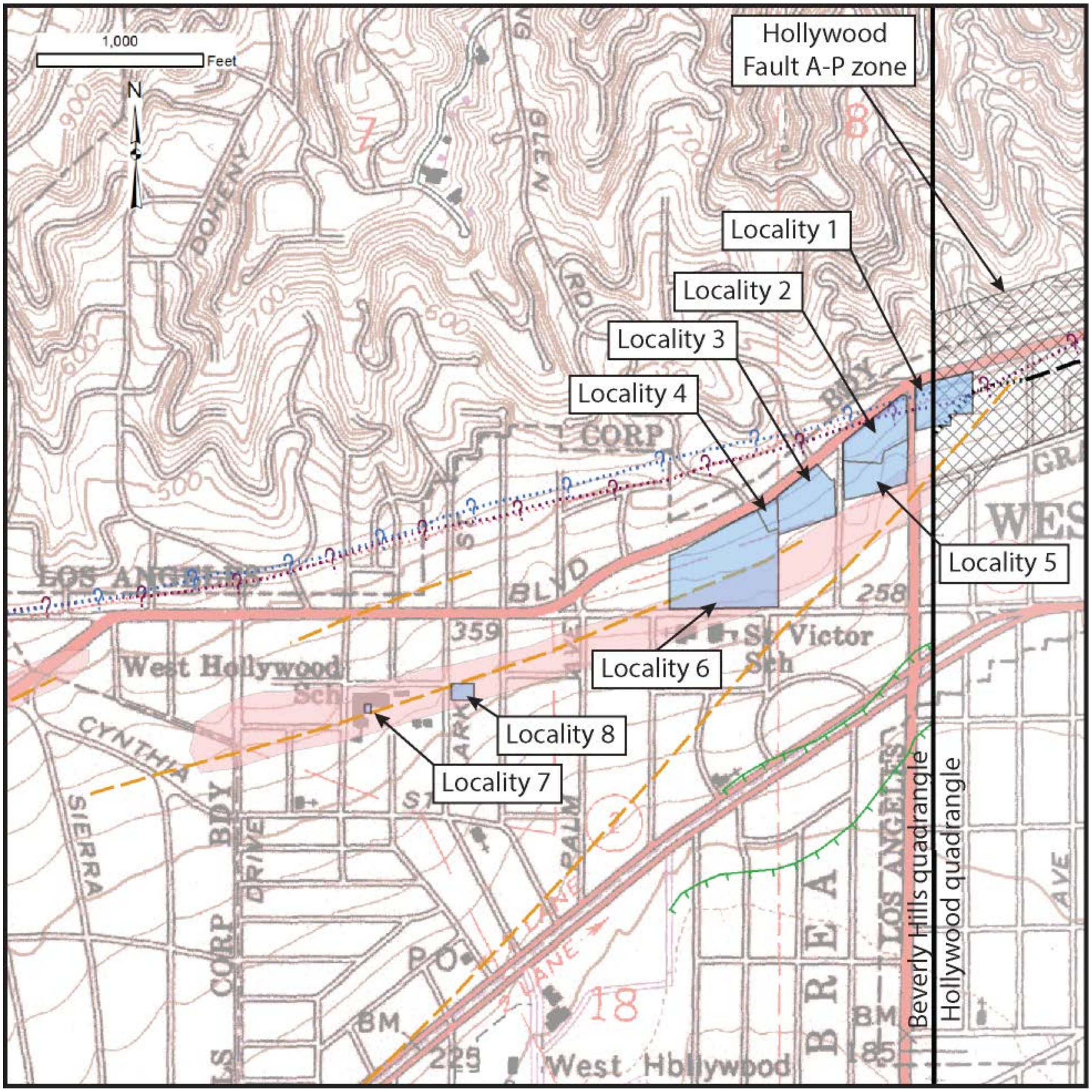

Figure 22- Study site boundaries (light blue boxes) where investigations provide data relevant to evaluation of the Hollywood Fault Zone in the study area (localities 1 through 8, discussed in text). See legend on Plate 1 for fault types and mapping sources. Shaded area is the approximate limit of the "fold scarp" identified by Dolan *et a*l. (1997).

Locality 1 – Sunset Millennium East

Harza (1998, Figure 22 – Locality 1) identified two zones of faulting: a northern and a southern fault zone. Observations and interpretations of the boring data and fault trench exposures at the site indicate the "northern fault zone" does not offset an argillic soil unit estimated to be a minimum of 120,000 years old based on soil profile development. This northern fault zone includes several strands, which reportedly strike between N50°E to N70°E, and dip 50° to 60° NW. Striations and slickensides observed along fault planes in the bucket auger borings and the fault trench indicate these faults exhibited primarily north-side-down dip-slip motion.

The "southern fault zone" (herein referred to as Fault 1) was interpreted from a transect of continuous core borings and observed in bucket auger borings as a northeast striking, southeast dipping fault that vertically offsets Quaternary alluvial deposits at least 115 feet and acts as a significant groundwater barrier. Harza (1998) recommended a building setback zone for Fault 1 as a precaution until further studies could be done. Recent work, including observations from down-hole logged bucket auger borings and radiocarbon dating of the sediments by William Lettis & Associates, Inc. (2004) determined the Fault 1 consists of three distinct strands (D, E, and F in Figure 23) and is active. Fault 1 was observed during down-hole logging of additional bucket-auger borings to generally strike N50° to 55°E and dip from 53° to 56° SE. Charcoal/carbon samples from faulted soil horizons revealed dates about 9,910 to 10,190 ybp, and 15,250 to 16,650 ybp. They also reported an unfaulted soil horizon above fault strand D to be 8,590 to 8,990 ybp, suggesting a minimum age of faulting. They suggested, because fault strands D, E, and F all terminate at approximately the same stratigraphic position, these three closely spaced splays ruptured together in the most recent earthquake. Based on the detrital charcoal samples, they concluded the most recent surface-rupturing earthquake on Fault 1 occurred between ~8,500 and 10,000 years ago.

Locality 2 – Petersen After Sunset site

Four faults were identified by William Lettis & Associates, Inc. (1998c) at locality 2, which are overlain by multiple unbroken Pleistocene soils. The southernmost fault offset Pleistocene alluvium, but is overlain by continuous unbroken Holocene deposits. Through additional review of the subsurface data collected at the site it was recognized that a buried Pleistocene marine wave-cut platform existed at the site and was offset by the northern fault zone at depth. The abrasion platform consists of a gently dipping, planar surface of quartz diorite bedrock, overlain by a thin veneer of beach sand with smooth, rounded, non-quartz diorite cobbles and pebbles and serves as a useful subsurface marker unit. The consultants estimate the age of this marine wave-cut platform is between 400,000 to 900,000 years old based on age estimates of the oldest paleosols stratigraphically above it. Based on their investigation, they document up to 17° of platform tilting between fault-bound blocks; however, no measurable evidence of folding or tilting was observed in the overlying late Quaternary sediments at the site.

Locality 3 – Sunset Millennium

A study by William Lettis & Associates, Inc. (1998b), located at the southwestern intersection of Alta Loma Road and Sunset Boulevard (locality 3), mapped four minor faults crossing the site at depth. They report these faults are part of the "northern fault zone" identified at Localities 1 and 2 and offset the marine wave-cut abrasion platform by as much as 60 feet, but were classified as inactive since they do not offset multiple overlying late Pleistocene paleosols. These faults are considered secondary normal faults within the hanging wall of the Hollywood Fault, and not the main trace of the Hollywood Fault itself, which the consultants infer must lie well south of Sunset Boulevard at this location.

As previously summarized in Hernandez and Treiman (2014), the gently sloping buried marine abrasion platform consists of one, and possibly two, paleo-marine terraces in this area, with a paleo-sea cliff along the northern edge of each terrace William Lettis & Associates, Inc. (1998c). This is significant because it appears many of the scarps and slope breaks noted along the base of the Santa Monica Mountains, which were previously thought to be associated with the Hollywood Fault, are now interpreted as paleo-sea cliff edges, and not indicators of active faulting.

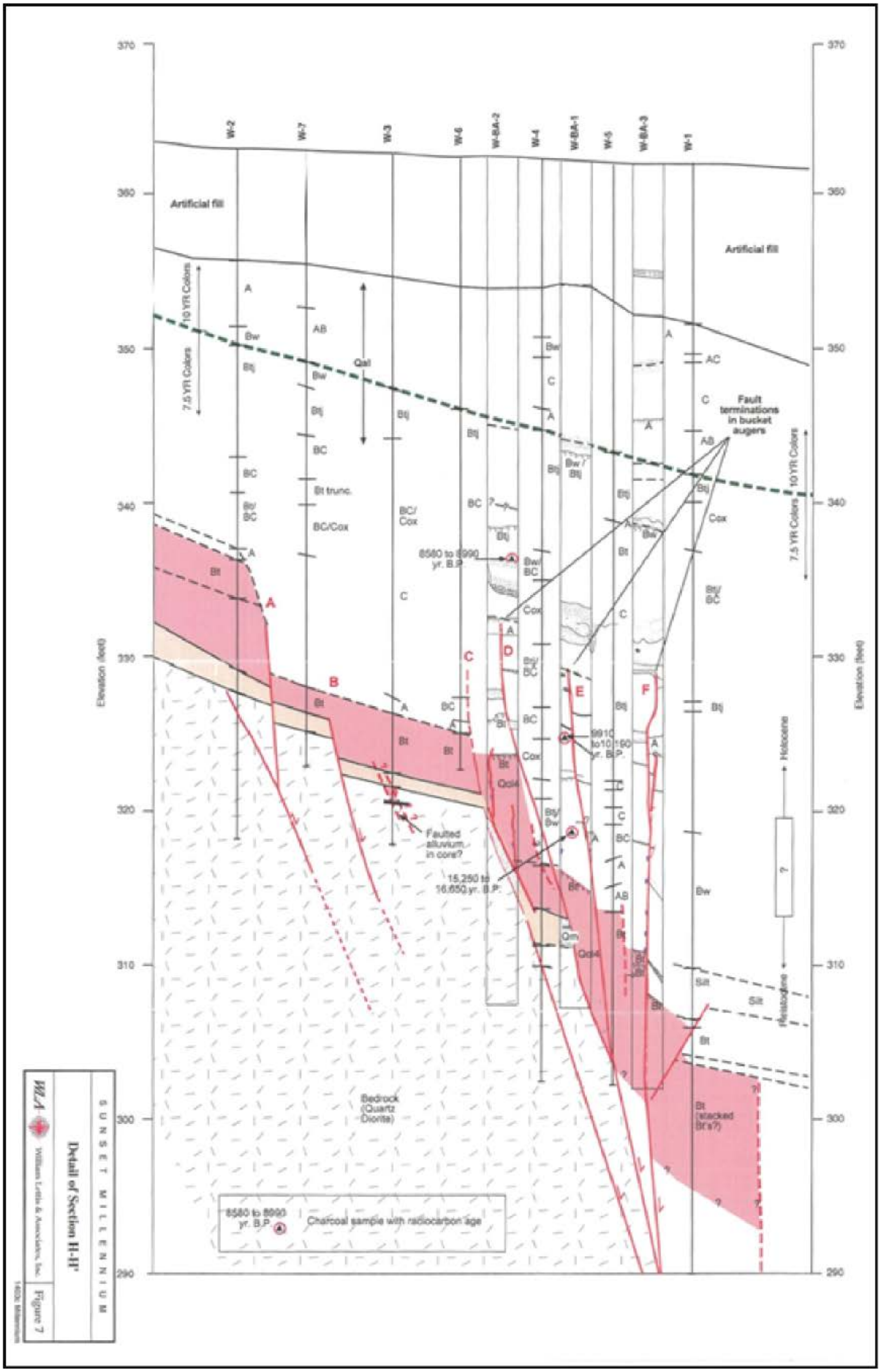

Figure 23 – Geologic cross section showing upward terminations of fault strands D, E, and F within Fault 1 at Locality 1; modified from William Lettis & Associates, Inc. (2004).

Locality 4 – Sunset Plaza

William Lettis & Associates, Inc. (2007b) performed another fault investigation south of Sunset Boulevard at Locality 4 and found no active faults at the site. Three inactive secondary faults were encountered, which were described as part of the inactive "northern fault zone" of Localities 1, 2, and 3. They reported these faults are overlain by continuous and unbroken Pleistocene soils.

Locality 5 – 9056 W. Sunset Boulevard

At Locality 5, Earth Consultants International (1999a) encountered six faults in their fault investigation. Here the marine abrasion platform was offset and tilted, but was overlain by unbroken late Pleistocene soils in all of their borings; indicating no Holocene faulting occurred at this location. Fault 1 (from Locality 1) underlies the site and was also judged to be inactive, based on apparent continuity of pre-Holocene stratigraphy overlying the fault tip as interpreted from their borings. However, the stratigraphic correlations are not clearly continuous and some Holocene offset cannot be precluded. Because these faults do not significantly offset the quartz diorite basement, Earth Consultants International (1999a) concluded the principal strand of the Hollywood Fault must lie farther to the south of this site.

Locality 6 – 8600 W. Sunset Boulevard

Interpretation of subsurface data from a fault investigation at Locality 6 suggests an active strand of the Hollywood Fault crosses the southeastern corner of this site. Feffer Geological Consulting (2016) drilled several continuous core and bucket auger borings, as well as CPTs along two north-south transects to investigate for subsurface faulting. Based on the samples collected from the borings, the consultants identified two major alluvial packages: Holocene alluvium and Pleistocene alluvial fan deposits. The Holocene alluvium contains at least four weakly developed soil horizons, while the Pleistocene deposits possess three well-developed argillic soils. Based on stratigraphic anomalies identified in both transects, the consultants identified three faults in a zone trending northeast to southwest across the site. In general, the faults identified dip steeply to the north with an apparent reverse, south-side down sense of slip. Of these faults, only Fault 1 (the southernmost fault) was interpreted to be active. This conclusion was based on offset of an approximately 30ka soil horizon at the site and correlation with the active faulting demonstrated at locality 1 (WLA, 2004) to the northeast. Additionally, their cross section depicts the base of the oldest Holocene alluvial unit offset by Fault 1. The age of this unit is reported to range from 5,000 to 17,000 years bp. They state Fault 1 "may define a northern portion of the Hollywood Fault Zone" and further postulate the main trace of the fault zone "is likely located south of the project site."

Locality 7 – West Hollywood Elementary School

Ninyo and Moore (1999) performed a Phase II environmental assessment at West Hollywood Elementary School (Figure 22 – Locality 7) to evaluate potential hydrocarbon-contaminated soils associated with a former underground storage tank (UST), which was removed in 1997. For their investigation, they drilled six hollow-stem auger borings to depths of approximately 26 feet below existing ground level. The scope of this study did not include investigating for active faulting at the site; however, review of the boring logs suggests a groundwater barrier exists near the location of the former UST. Groundwater is consistently encountered at elevations ranging from approximately 312 to 315 feet msl in the northerly borings, and is not encountered at all in the southerly borings, which were drilled down to about 298 feet msl. Therefore, it appears there is at least a 17-foot vertical drop in groundwater level over a horizontal distance of about 15 feet. Based on the presence of geomorphic features suggestive of faulting to the west and east of this site, which roughly project through this site, the observed groundwater barrier may be fault-related.

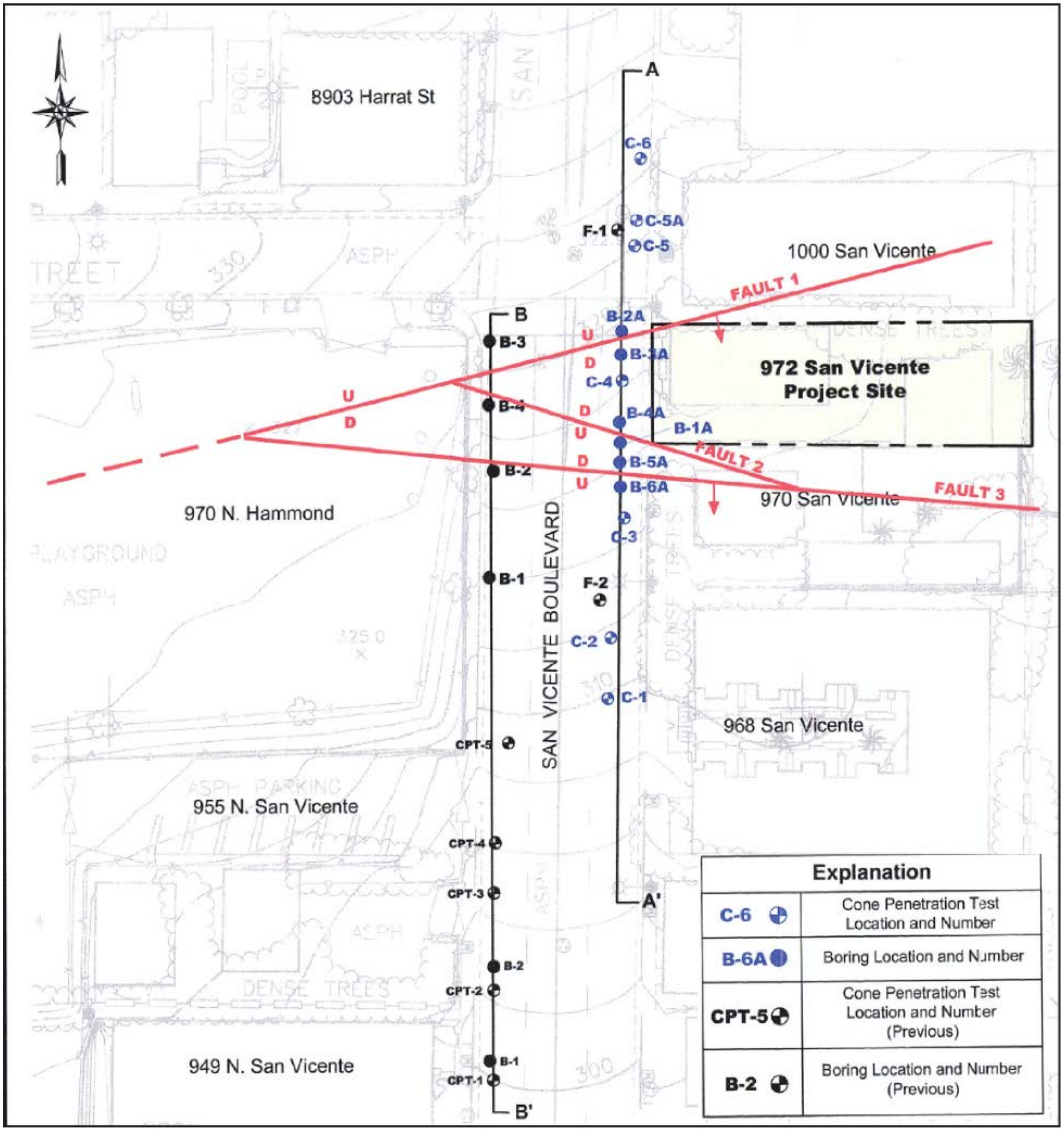

Figure 24 - Fault and boring/CPT location map from Helms (2017) along N. San Vicente Boulevard in the City of West Hollywood. Note difference in fault trend between Fault 1 and Faults 2 and 3, which are truncated, suggesting Fault 1 is the controlling and more recently active fault.

Locality 8 – 972 San Vicente Boulevard

Helms (2017, Figure 22 – Locality 8) drilled several continuous core borings and CPTs, and used subsurface data from previous fault studies adjacent to the site, to construct two subparallel transect profiles along San Vicente Boulevard. He identified a fault zone consisting of three steeply south-dipping fault strands, and observations and interpretations of the boring data indicate none of the fault strands offset a Pleistocene alluvial fan deposit determined to be a minimum of 20,000 years old based on radiometric dating. The northernmost fault strand reportedly strikes approximately N70°E. This fault was intersected by one of the borings where is had a measured dip of about 80°. The author inferred this northern fault dips to the south based on stratigraphic relationships observed in the adjacent borings, and further notes this strand exhibits a strong component of strike-slip motion based on observed thickness changes of the alluvial units and opposite sense of vertical separation compared to the other strands. The middle and southern fault strands have notably different orientations, trending about N50°W and N85°W, respectively. However, the spacing of the borings along the western transect is noticeably wider, which would allow for a range of feasible trends for these two faults. These strands are depicted as being truncated by the northern strand a short distance west of San Vicente Boulevard (Figure 24) suggesting the northern strand is the most recently active fault in this zone. Overall, because none of the faults offset the late Pleistocene alluvial fan layer, Helms concludes they are not active. However, he notes a subtle break in slope approximately 25 meters north of this site, which he comments "may indicate the possible location of a strand of the Hollywood Fault."

SUMMARY OF AVAILABLE DATA FOR THE NEWPORT-INGLEWOOD FAULT ZONE

LITERATURE REVIEW

The Newport-Inglewood Fault Zone (NIFZ) is a northwesterly trending series of folds and faults, which form an alignment of prominent hills and mesas extending from Newport Beach to the Cheviot Hills. The first detailed mapping of the NIFZ was done by Poland *et al*. (1959) and Castle (1960a). A more detailed description of the geologic literature, fault location, and geometry is provided in Bryant (1985). It is not the purpose of this report to reevaluate the traces mapped by Bryant (1985), but to incorporate the observations made from new data available as it applies to potential faulting north of the terminus of the current APEFZ.

Ericskon and Spaulding (1975)

This study was performed to evaluate the potential for surface subsidence related to oil production in the Beverly Hills (East) oil field, which is located just east of the Cheviot Hills. During their study of the subsurface geology of the oil field, Ericson and Spaulding (1975) evaluated the structural geometry of the NIFZ. They noted the subsurface structural patterns indicate the maximum principal stress direction in this area is north-south. Furthermore, they state the NIFZ appears to bifurcate into more than one surface trace as it approaches the SMFZ. They depict two of these faults strands trending across the Ballona Gap, the westerly of the two they term the "Inglewood Fault" and the eastern one they refer to as the "West Pico Fault" (Plate 1). They note the West Pico Fault also serves as a major structural boundary separating highly complex geology to the west from less complicated geology to the east. This fault similarly affects the shallow freshwater aquifers south of the oil field.

Dark *et al*. (2011)

Dark *et al*. (2011) documents historical wetland distribution within the Ballona Creek watershed. The authors reviewed over 300 historical documents, including maps, photographs, survey notes, and illustrations with a view towards reconstructing the various types and areal limits of wetlands habitat for the time period from 1850 to 1890. Within the current fault evaluation study area, the authors identified a significant wetlands complex referred to as the La Cienega wetlands (Figure 25). This system of freshwater marshes surrounded by alkali meadows, alkali flats, and wet meadows stretched approximately 10 miles from Hollywood to Inglewood. This study is useful for determining where the NIFZ crosses Ballona Gap because the fault zone in this area is a known groundwater barrier. This habitat data is also helpful in postulating locations of more northerly fault strands as the NIFZ approaches the SMFZ

SUMMARY OF ADDITONAL DATA REVIEWED FOR ALL FAULTS

AERIAL PHOTOGRAPHIC INTERPRETATION

Vertical aerial photographs – 1927-1928

Aerial photographic interpretation was performed primarily to look for visual and geomorphic features suggestive of active faulting and also to verify the location and activity of the fault traces mapped by others (Plate 1). This was accomplished using stereo-paired aerial photographs from two flights conducted by Fairchild Aerial Surveys in 1927 and 1928. Even at these dates, urban development of the Los Angeles area obscures many portions of the land surface, which makes it difficult to identify geomorphic and tonal features. Even so, many features of the landscape are still evident in these photographs, especially in areas where development is minimal. Fault traces mapped by others were also checked against these photos for geomorphic evidence of Holocene

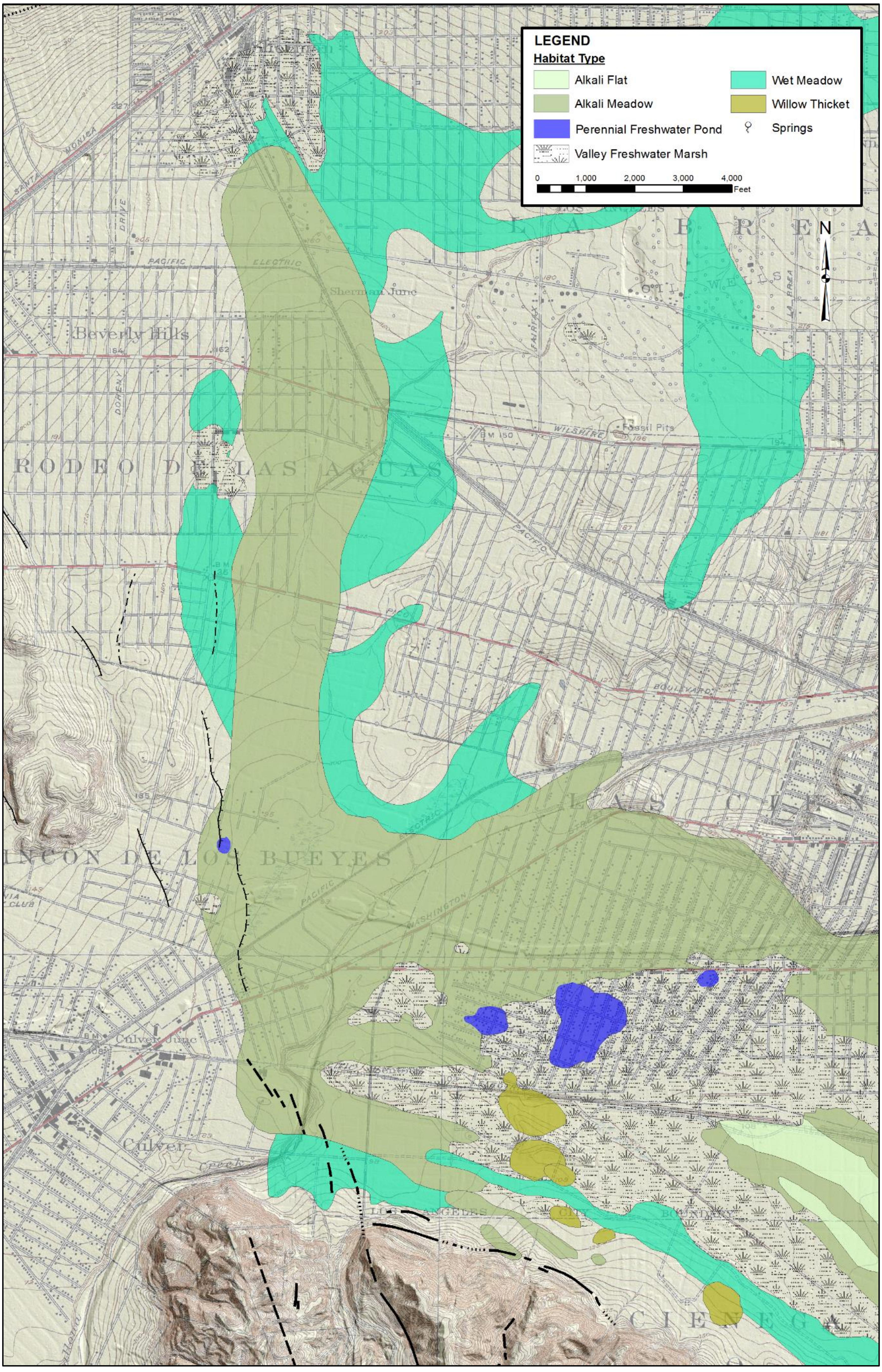

Figure 25 - Reconstructed wetlands environments by Dark *et al.* (2001) in the Ballona Gap region. Dark black lines are faults previously zoned by Bryant (1985); thin black lines with tick marks are topographic scarps; thin dashed black lines are notable breaks in slope.

activity and location accuracy. The various mapped traces and lineaments are annotated and included on Plate 2.

Historic oblique photographs – 1921-1938

Vintage oblique aerial photographs by Spence Aerial Surveys were also available for this evaluation. These photos are taken at different angles and at much lower elevations than the vertical aerial photos, which help to identify and interpret geomorphic features of the landscape. Another benefit of these oblique aerial photos is that they also offered an independent check of those features interpreted from the vertical aerial photos and topographic maps.

TOPOGRAPHIC MAP INTERPRETATION

Historic topographic maps – 1925-1926

A series of topographic maps was prepared in the 1920s for the County of Los Angeles at a scale of 1:24,000. These maps are notable for two reasons. First, they capture the landscape at a time when much of the local land development had either not occurred or was of a less disruptive nature. Secondly, these maps have a 5-foot contour interval and were drawn by topographers with an excellent sense of landform. As a result, these maps provide a very illuminating view of the landscape and reveal numerous features that are suggestive of tectonic influences. This evaluation analyzed the topography as depicted on the Sawtelle 6-minute quadrangle from 1928 and the Hollywood and Topanga Canyon 6-minute quadrangles from 1926 (all at an original scale of 1:24,000). An interpretive map from these topographic bases, delineating locally incised and/or deflected drainages, breaks in slope, scarps, and lineaments is provided on Plate 2.

LIGHT DETECTION AND RANGING (LiDAR) DIGITAL ELEVATION MODEL

Available optical remote sensing imagery was used to more accurately evaluate the geomorphology associated with the Santa Monica, Hollywood, and Newport-Inglewood Fault Zones in this study area (Los Angeles Regional Imagery Acquisition Consortium (LARIAC), 2006). An airborne Light Detection and Ranging (lidar) survey was taken of Los Angeles County in 2006 as part of a collaborative acquisition program for digital aerial imagery data which has included the participation of 10 County departments, 30 municipalities, and four other public agencies. The lidar survey consisted of scanning the ground surface with a pulsing laser mounted in an airplane. The distance from the laser source to the ground surface is measured based on the time required for the laser beam to be reflected back to the source. Based on the various arrival times a digital model of the ground surface can be generated. From this model hillshade relief maps were derived with 45° and 315° illumination angles at 30°and 45° above the horizontal.

FIELD INSPECTION

One field visit was made in January 2015 to check various geomorphic features identified in the aerial photographs, historic maps, and hillshades. Additionally, various slope breaks were observed and recorded using a handheld GPS receiver.

SEISMICITY

In the Los Angeles region, several historical earthquakes generated strong shaking in the vicinity of the study area, including: the 1971 M6.6 San Fernando, 1987 M5.9 Whittier Narrows, 1988 M5.0 Pasadena, 1991 M5.8 Sierra Madre, and 1994 M6.7 Northridge events. None of these major earthquakes were associated with the Hollywood, Santa Monica, or northern Newport-Inglewood Fault Zones. Regional seismicity data covering the period from 1981 to 2016 (Hauksson *et al*., 2012) does indicate there is a diffuse pattern of seismic activity in the study area (Figure 26). Of particular interest is a series of minor earthquakes temporally and spatially clustered in the area of the eastern Cheviot Hills (Figure 27). The sequence consisted of approximately 70 earthquakes between 2001 and 2003. The two largest earthquakes recorded were a M4.2 event on September 9, 2001 followed by a M3.0 event on October 22. The moment tensor solution available for the larger earthquake indicates a slightly oblique strike-slip faulting mechanism with nodal planes trending approximately north-south and east-west (Hauksson *et al*., 2001). Based on the overall east-west pattern of the epicenter cluster, it seems this event occurred on a fault plane oriented about N81°E, dipping 83° to the north at a depth of approximately 7.6 km. KGS (2016) notes the location and trend of this event cluster is immediately adjacent and parallel to their postulated Potrero Canyon Fault East.

Subsequent to the 2001-2003 sequence, two moderate earthquakes of magnitude M3.2 and M3.4 occurred in September 2012 north of the previous cluster (Figure 27). These events do not have nodal plane solutions so it is not clear whether they might be associated with the Santa Monica Fault or potential strands of the Newport-Inglewood Fault Zone; however, their northwest-southeast alignment might suggest they are related to a potential strand of the northern NIFZ.

Most recently, two earthquakes greater than a magnitude 3 occurred within the study area. First, a M3.1 earthquake happened on May 2, 2017 in the area where the Santa Monica Fault Zone crosses Santa Monica Canyon, near Pacific Palisades. Focal mechanism data for this earthquake is available and it seems the most likely nodal plane is N60°E dipping 64° north, which is similar to the local trend of the surface fault trace of about N75°E (Figure 27). Based on the data, this fault plane ruptured with a left-lateral reverse oblique sense of motion at a depth of approximately 9.6 km. Most recently, a M3.6 earthquake occurred farther to the north beneath the Santa Monica Mountains. The focal mechanism data show this was almost a purely reverse slip event on a fault dipping either 53° north or 37° south at a depth of 10.5 km. Which nodal plane most likely represents the rupturing fault cannot be reasonably determined since the basal thrust fault of the SMFZ dips north, but there are also south-dipping backthrusts in the hanging wall. These two events indicate the overall SMFZ remains seismogenically active and capable of producing future strong earthquakes, which may rupture the surface.

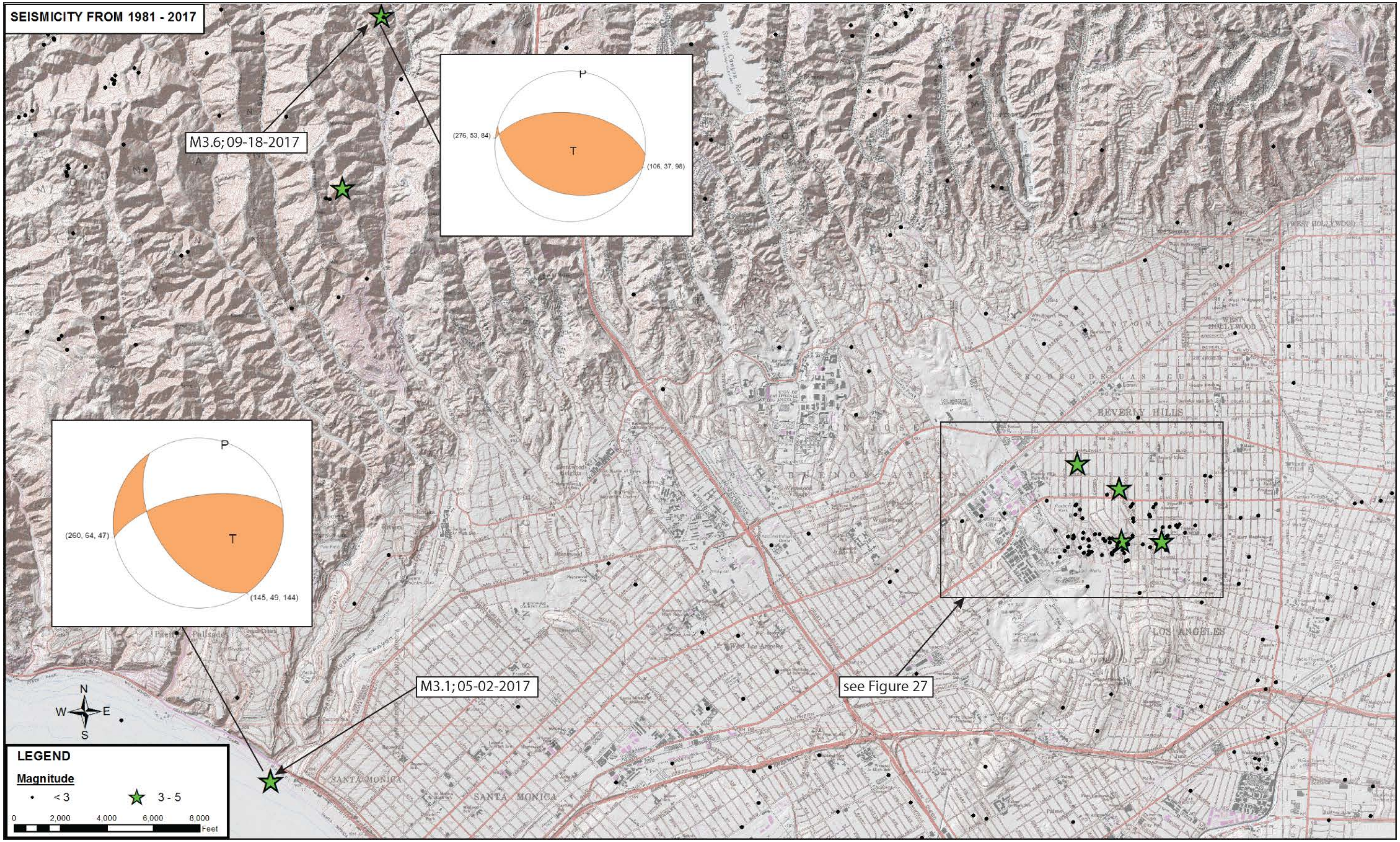

Figure 26 - Regional seismicity from 1981-2016 for western Los Angeles Basin, including epicenter and focal mechanisms of M3.1 and M3.6 earthquakes that occurred within the study area 2017. Inset box indicates area of interest depicted in Figure 27. [epicenter locations from Hauksson *et al.* (2011); 2017 epicenter location and focal mechanism data from SCEDC (2013)]

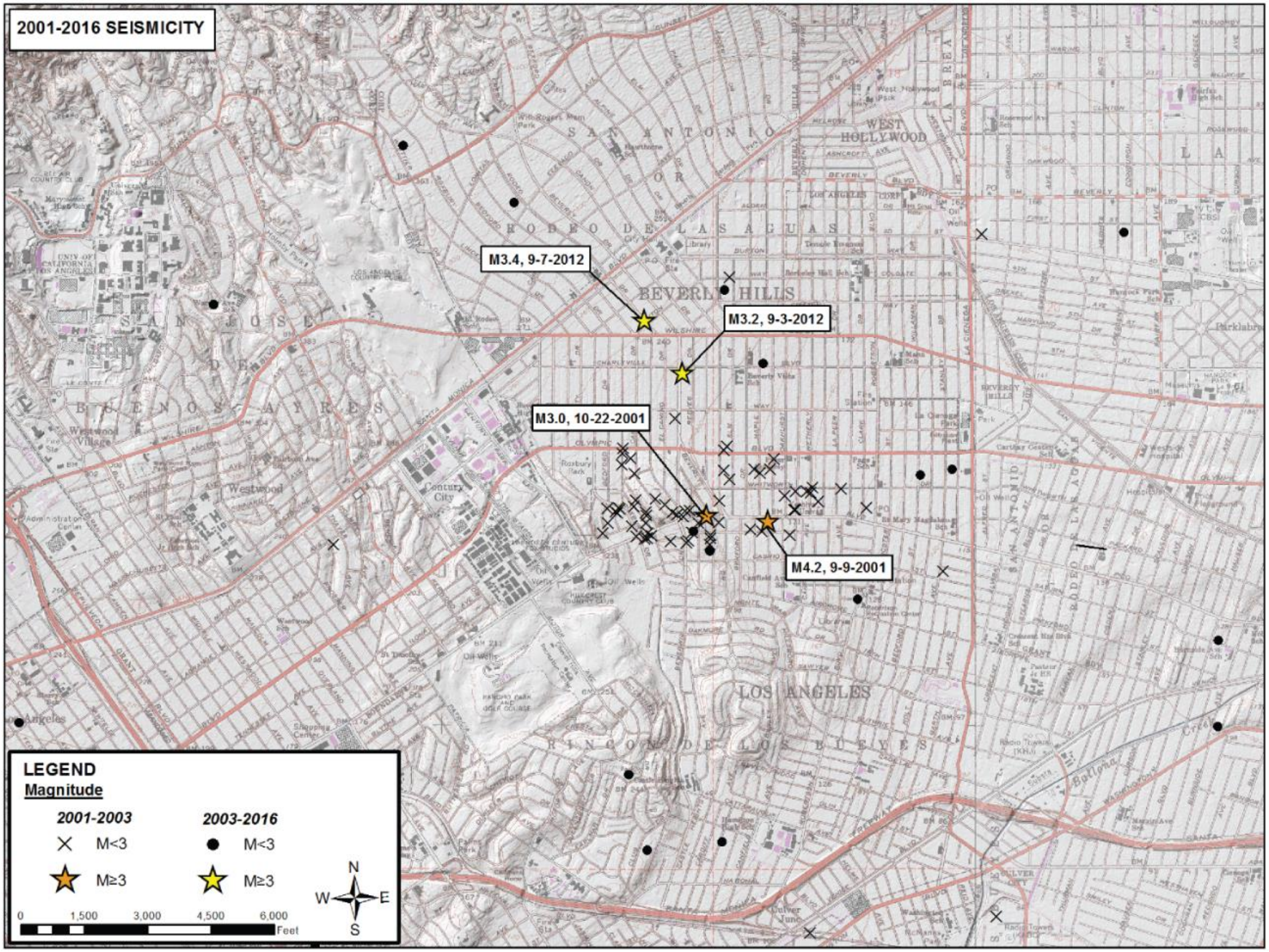

Figure 27 - Locations of earthquakes in the Cheviot Hills area between 2001 and 2016, including the epicenters from the 2001-2003 earthquake series. Stars are larger earthquakes referred to in the text.

DISCUSSION AND CONCLUSIONS

To aid discussion each of the faults and geomorphic features evaluated for this study will be discussed individually. This includes the western portion of the Hollywood Fault, the Santa Monica Fault Zone, the northern portion of the Newport-Inglewood Fault Zone, and the West Beverly Hills Lineament.

HOLLYWOOD FAULT

The Hollywood Fault, which is in close proximity to the base of the Santa Monica Mountains in the Hollywood quadrangle to the east (Hernandez and Treiman, 2014), turns to the southwest near the eastern edge of the study area and trends away from the mountain front. The fault is expressed here by an over-steepening of the alluvial fans at the base of the mountains and several small scarps and subtle breaks in slope visible on the historic topographic maps. Some less-prominent scarps near the base of the hills west of West Hollywood, are thought to be related to a paleo-sea cliffs associated with buried marine terraces identified in the area by William Lettis & Associates, Inc. (1998c). Additionally, the scarps noted along Sunset Boulevard in this same area are likely related to grading for the original road construction. The significant break in slope observed south of Santa Monica Boulevard along the eastern map boundary likely marks the distal extent of the alluvial fan emanating from Rising Glen Road canyon, and is probably not related to faulting due to a lack of discernable scarps or slope breaks east or west of the feature.

As seen on Plate 2, south of Sunset Boulevard there is a semi-continuous series of slope breaks extending over 1 km west from Larrabee Street, which are on trend with Fault 1 from the fault investigation at 8600 W. Sunset Boulevard (Feffer Geological Consulting, 2016). In that study, Fault 1 was determined to be active. One of these breaks in slope was noted by Helms (2017) just north of three inactive faults encountered at 972 N. San Vicente Boulevard. He concluded the feature might represent a more northerly strand of the Hollywood Fault zone. Additionally, a noted local groundwater barrier at West Hollywood Elementary School is also in-line with this series of topographic breaks suggesting it is also related to faulting.

SANTA MONICA FAULT ZONE

To facilitate discussion of this complex zone, the fault is divided into five segments (Figure 28). The westernmost segment (Segment 1) begins where the Santa Monica Fault comes onshore at Pacific Palisades and extends to the northeast towards Santa Monica Canyon, primarily as a single trace. Segment 2 is much wider and consists of several strands trending east through the City of Santa Monica and south of Brentwood Knoll. Segments 3 and 4 trend more northeasterly and are expressed as a semi-continuous series of linear scarps in the older alluvial fan deposits, with Segment 4 specifically paralleling Santa Monica Boulevard as it enters the Cheviot Hills. East of the Cheviot Hills and the WBHL, Segment 5 is mapped as a single trace in the Benedict Canyon Wash alluvial plain trending to the northeast towards the mapped location of the buried Salt Lake Fault.

Segment 1

This segment of the SMFZ was the earliest recognized strand of the fault zone based on the exposure (now concealed by grading) at the mouth of Potrero Canyon. At this location, the base of the Stage 5e marine terrace is offset approximately 30 meters (McGill, 1989) and there are two prominent southeast-facing scarps in the terrace surface immediately above, and in alignment with, the fault trend. These scarps are continuous across the incised terrace surface

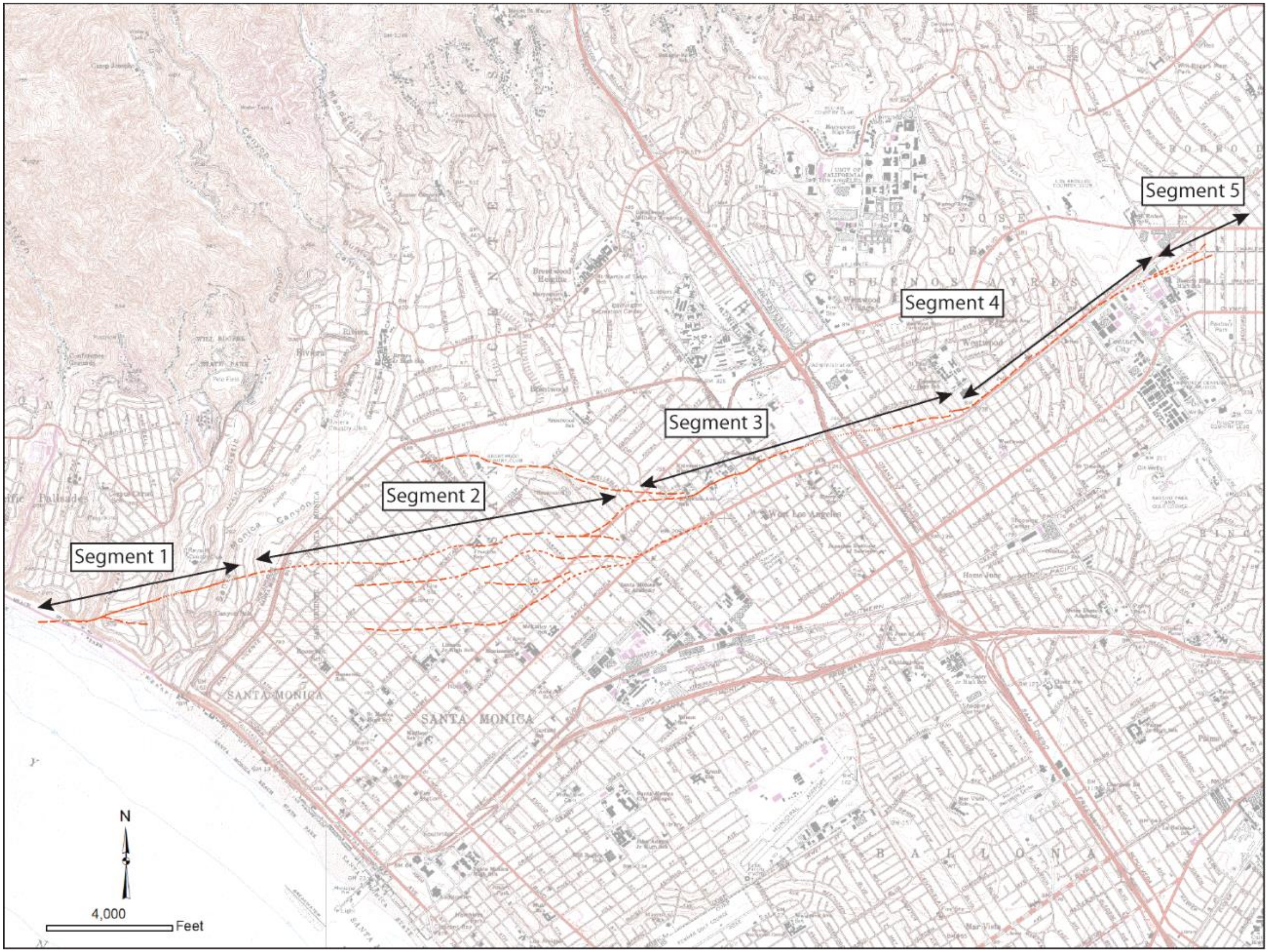

Figure 28 - Index map to Santa Monica Fault Zone segments discussed in text. Red lines are faults identified for zoning.

and range in height from 4 to 9 meters (Figure 29). The only subsurface investigation of this segment of the SMFZ was performed by Johnson (1932) and included studies of the uplifted terrace surfaces east of Potrero Canyon for geomorphic indicators of fault movement, stream gradient changes in the adjacent canyons, and two different types of geophysical surveys in an effort to map out the near-surface trend of the fault. He concluded the data collected indicated this segment was active. A secondary east-trending break in slope immediately south of the northeast-trending scarp is visible in the vintage topographic map of this area. KGS (2016) postulates this feature is fault-related (Plate 1), describing it as a Quaternary fault with unknown Holocene activity.

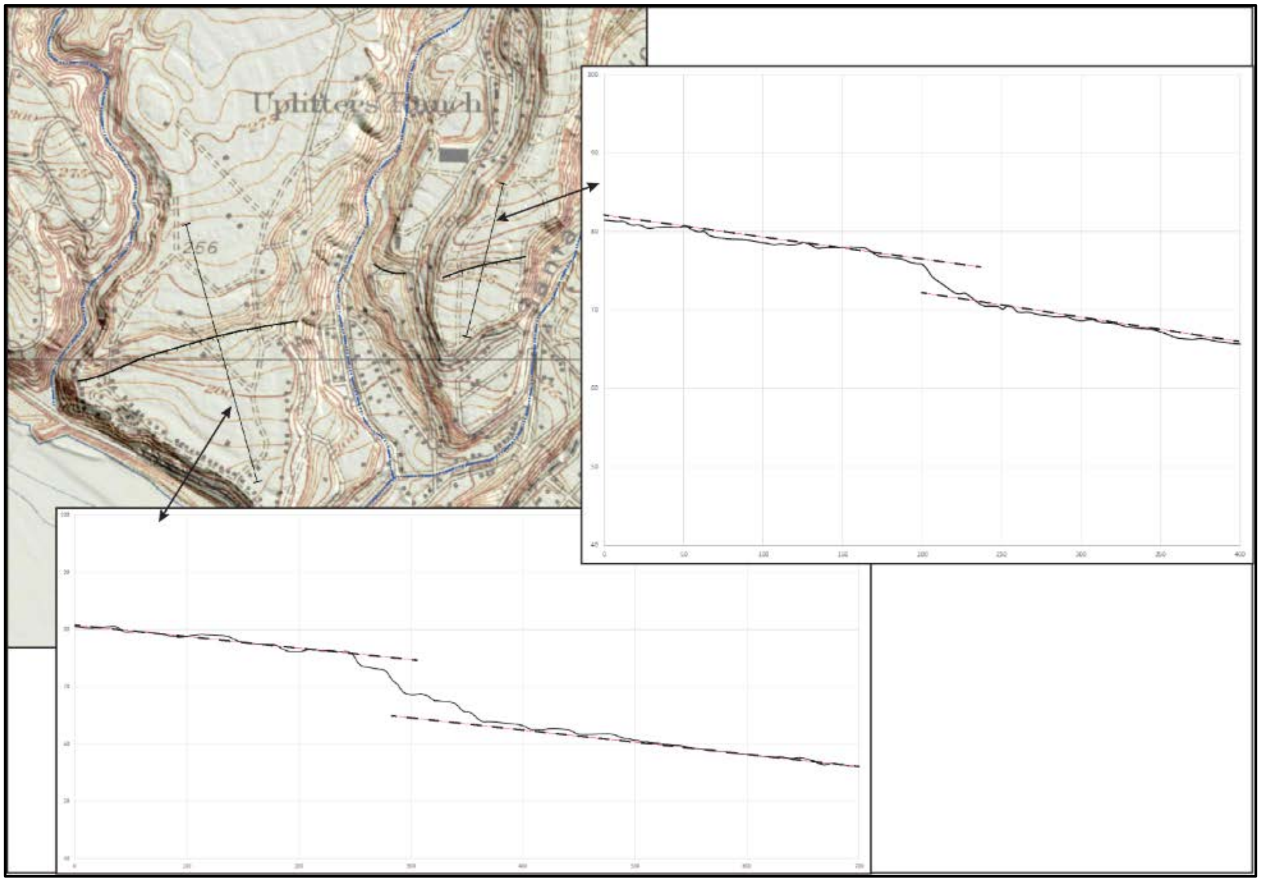

Figure 29 - Topographic profiles across two southeast-facing scarps in the marine terrace surface at Pacific Palisades. Scarp on the west is ~3 m, scarp on the east is ~1.5 m (5x vertically exaggerated). Base imagery is LA County lidar hillshade with 45° illumination angle; topographic base map is 1925 USGS 6' Topanga Canyon quadrangle map.

Segment 2

Between Pacific Palisades and West Los Angeles, the geomorphic expression of the SMFZ becomes more complicated. To the west and east, the fault is mainly expressed as a singular series of south-facing linear fault scarps, but in the Brentwood/Santa Monica area, the scarps appear to branch out in several splays, which generally step *en echelon* to the left. A prominent hill (Brentwood Knoll) and a low, continuous linear ridge extend along the northern portion of what appears to be an uplifted older alluvial fan surface, which is herein informally referred to as the "Brentwood fan." (Figure 30). This surface can roughly be divided into two portions, a more uniformly sloping western portion and a more irregular and eroded eastern portion. Overall, the western portion of the Brentwood fan surface maintains an approximately 1.5° dip to the south suggesting it has been uplifted, but not appreciably tilted or deformed since its formation (Figure 31a). The low ridge extending northwesterly from Brentwood Knoll forms a north-facing scarp, until it reaches a saddle at the northern apex of the Brentwood fan. At this point, it transitions into a more flat-topped scarp in the western half of the fan where it is more linear and subparallel to the adjacent Santa Monica Canyon drainage. The height of the scarp also diminishes to the west suggesting the northwestern edge of the Brentwood fan is possibly related to erosion, not faulting. However, in the eastern half of the Brentwood fan the northern scarp trend is relatively steep, slightly irregular, and aligned obliquely to the regional stream gradient suggesting it may, at least in part, be fault-related. Faulting is also suggested by the presence of the anomalous Brentwood Knoll, which rises up to 25 meters above the surrounding alluvial fan surface. A small exposure of Pliocene bedrock mapped by Hoots (1931) and Castle (1960a) along the northeastern margin of the hill, approximately 3 km out from the mountain front, lends plausibility to a fault origin for this feature. Also, in this eastern portion of the fan there is a broadly incised drainage swale and numerous subparallel linear slope breaks and scarps that roughly align with, and project toward, the Segment 1 fault trace. A stream drainage depicted on the 1925 topographic map is noticeably deflected around an uplifted portion of the fan bounded by two of these subparallel scarps (Figure 30 and 31b). KGS (2016) mapped a fault north of Brentwood Knoll and along the northern scarp that connects with the Segment 3 strand of the SMFZ (Plate 1). They noted the more northwesterly trend of the fault as it bends around Brentwood Knoll forms a local restraining bend, which would explain the upthrown bedrock and the uplifted and disrupted topography of the eastern Brentwood fan. The subparallel intra-fan faults then likely represent a positive flower structure caused by the resultant transpressional stress. Continuous scarps and breaks in slope, as well as a fold scarp by Dolan *et al*. (2000a) that broadens significantly to the west, were mapped along the southern edge of the Brentwood fan (Plates 1 and 2). These geomorphic features likely represent either additional high-angle faults in the hanging wall associated with the flower structure or the surface expression of the underlying blind reverse fault in the shallow subsurface.

There is sufficient evidence to conclude these features are fault-related and should be considered active and should be zoned. The scarp along the northeastern margin of Brentwood Knoll and the northern Brentwood fan also appears to be associated with active faulting; however, the northwestern scarp is not considered for zoning as it appears to be strongly influenced by erosion from drainages associated with Santa Monica Canyon. There is also no strong geomorphic evidence to suggest this northern strand, nor the southernmost strand, extends across Santa Monica Canyon to connect with Segment 1. The connection of the main Segment 1 strand with the flower structure of Segment 2 is based on an inferred projection along trend between both segments.

Segment 3

Extending east from Bundy Drive the fault is expressed geomorphically as a prominent south-facing linear scarp up to 12 meters high, about 3 to 4 km south of the mountain front (Figures 30-32; Plate 2). Between this scarp and the mountain front is a piedmont foreland consisting of uplifted and dissected older alluvial fans. Modern fan deposition is occurring downstream of the scarp, not at the range front, suggesting the most recent uplift is taking place at the scarp.

Subsurface studies at the Veteran's Administration Hospital property just west of Interstate 405 corroborate the general fault geometry exposed at Potrero Canyon of subvertical hanging wall oblique faults terminating into a blind low-angle reverse fault at depth (Crook and Proctor, 1992; Pratt *et al*., 1998; Dolan *et al*., 2000a; Catchings *et al.*, 2008, 2010). Fault investigations performed across the same scarp at both University High School and Brockton Avenue School located approximately 0.6 km and 1 km west of the hospital, respectively, also encountered high-

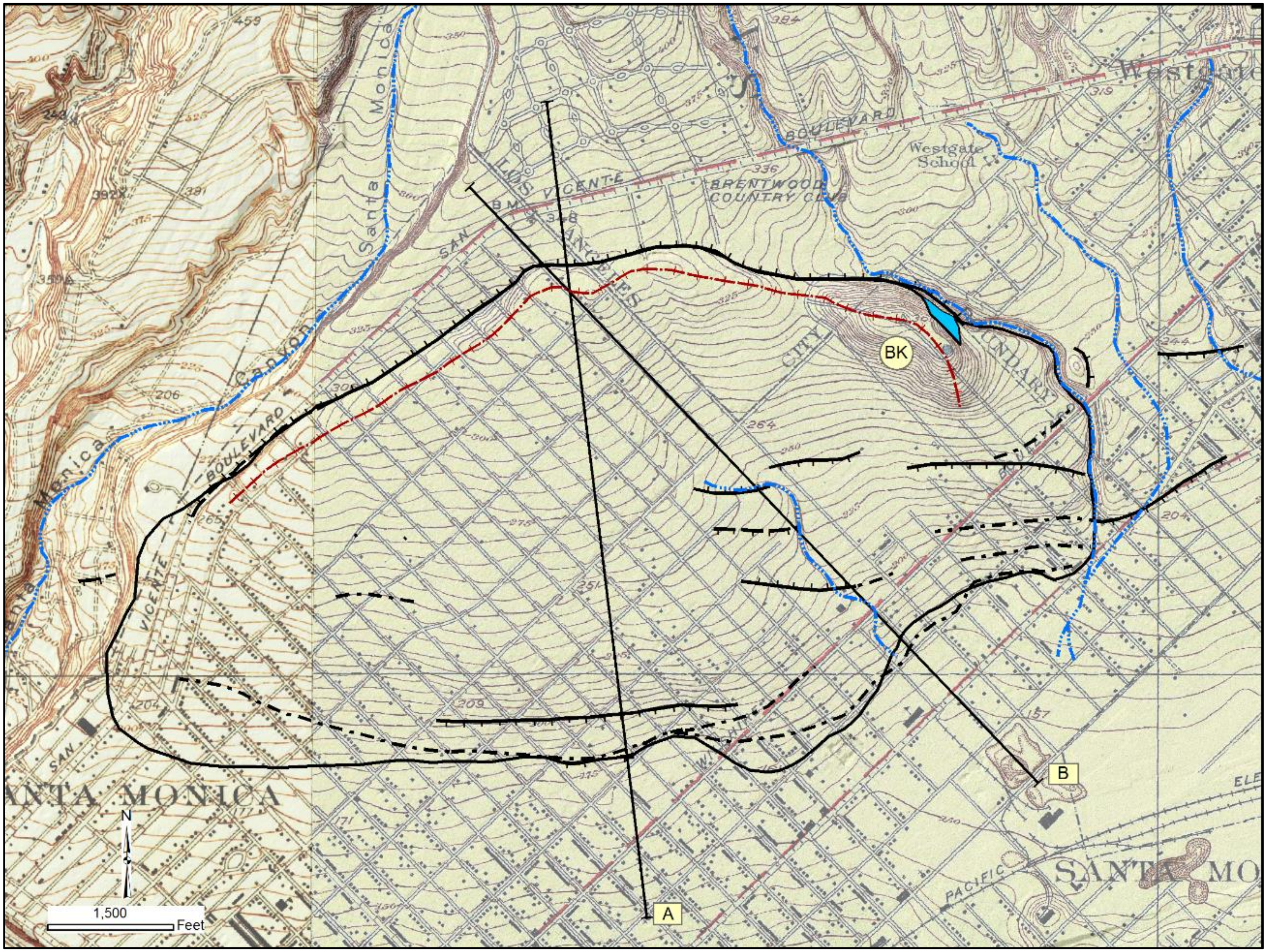

Figure 30 - Uplifted "Brentwood fan" showing breaks-in-slope (long-short dashed lines), scarps (black line with tick marks), scarp along northern margin (red line), stream drainages (blue lines), area of exposed Pliocene sedimentary bedrock (light blue shaded area), and topographic profile lines. Light gray oval shows uplifted intra-fan surface. BK – Brentwood Knoll topographic profiles are depicted on Figure 31. [Topographic base map: Sawtelle 6-min. (1925) and Topanga Canyon 6-minute quadrangles (1928)]

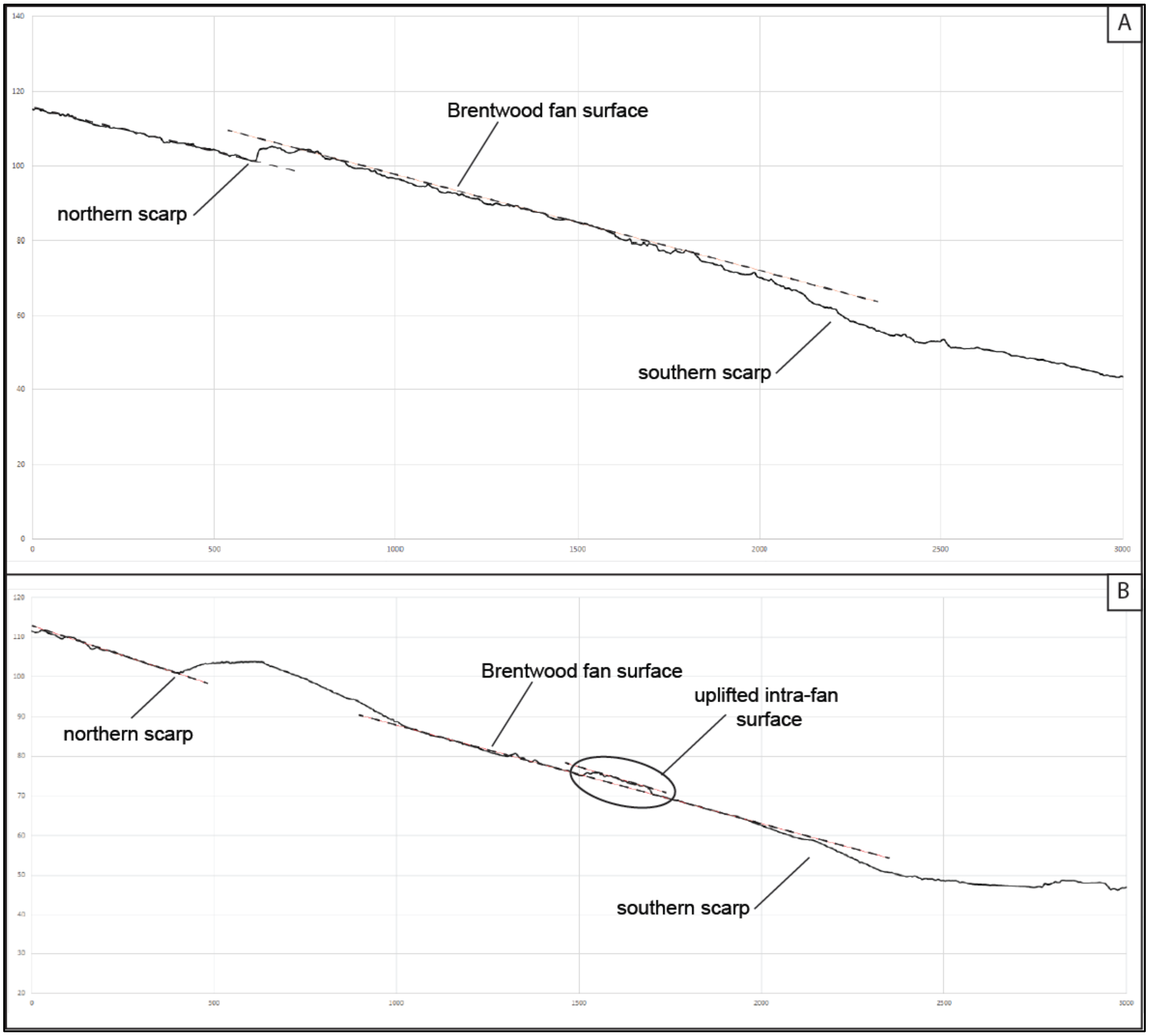

Figure 31 - Topographic profiles through the Brentwood fan. A) Profile showing north-facing scarp and Brentwood fan surface uplifted approximately 6 meters; B) Profile showing uplifted intra-fan surface uplifted approximately 1.5 m (10x vertically exaggerated)

angle faults. At these sites, several marker units within the late Pleistocene to Holocene alluvium were offset, indicating these faults are active. Farther west along the scarp, near the intersection of Bundy and Wilshire, Worley Parsons (2009) identified a significant groundwater barrier that is likely related to faulting. This same groundwater barrier was also identified by Crook and Proctor (1992) at a different site in the immediate vicinity, where it was associated with a fault observed in a foundation excavation (G.A. Brown, 1993, pers. comm., reported in Dolan *et al*., 2000a).

The main scarp is completely eroded where it crosses Sepulveda Canyon, but it clearly continues to the east (*i.e*. Segment 4). The fault investigation by AES (2015a,b) near the scarp at the intersection of Malcolm Avenue and Santa Monica Boulevard identified subvertical faults, which they concluded are active. This provides ample justification for connecting Segments 3 and 4 and continuing the zone across the Sepulveda Fan (Plate 3).

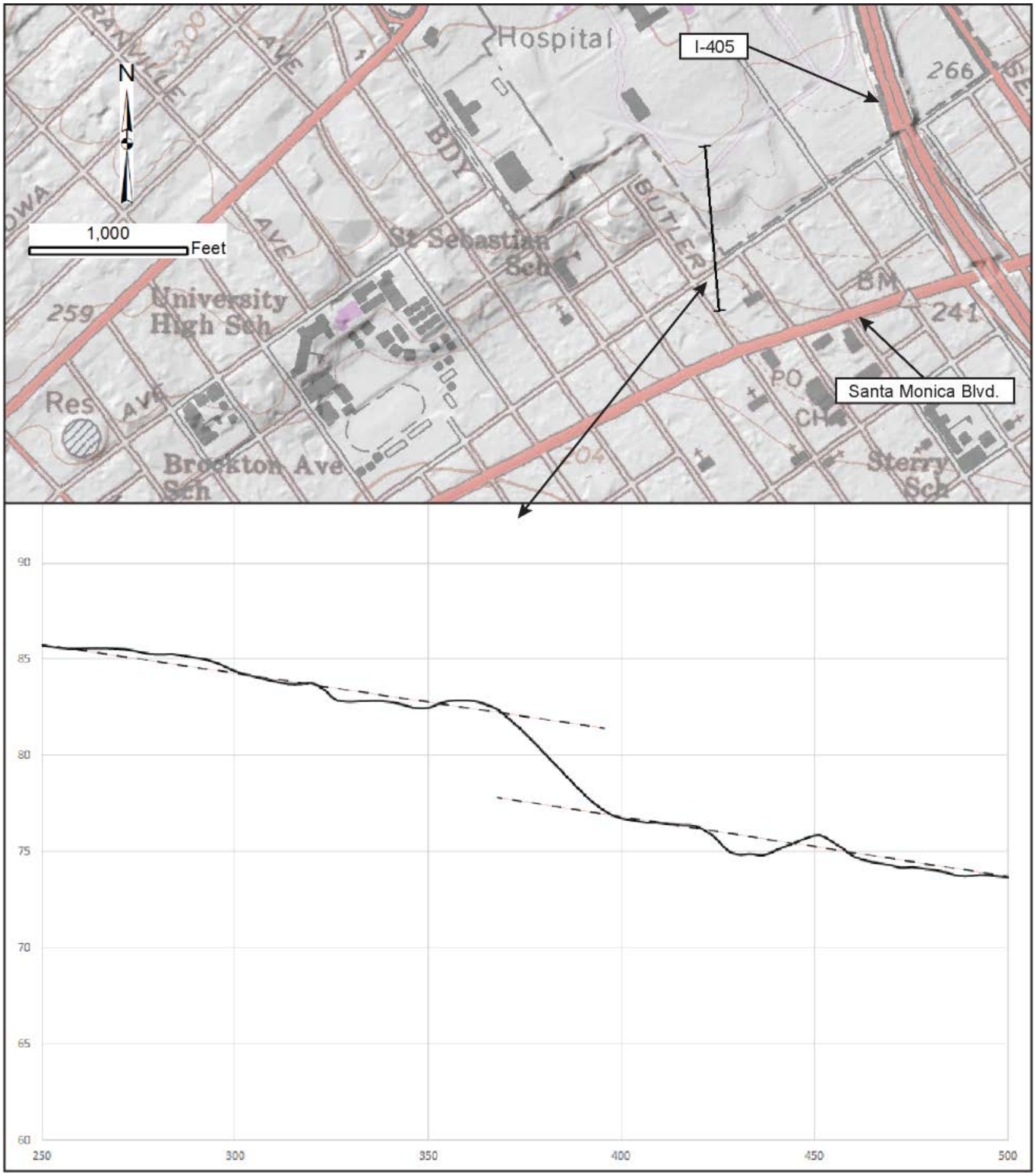

Figure 32 - Topographic profile across scarp at the Veteran's Administration Hospital. Scarp is ~1.5 m (5x vertically exaggerated). Topographic base map is modern USGS 7.5' Beverly Hills quadrangle topographic map draped over the LA County lidar hillshade with a 315° illumination angle.

Segment 4

Immediately east of Malcolm Avenue, the SMFZ scarp changes orientation from N70°-75°E to N50°E. Santa Monica Boulevard parallels this segment where scarp heights range from 7 to 12 m. This segment of the fault is highly linear and transects the Cheviot Hills, which consists of highly dissected Pleistocene fan deposits both north and south of the fault scarp. Examining

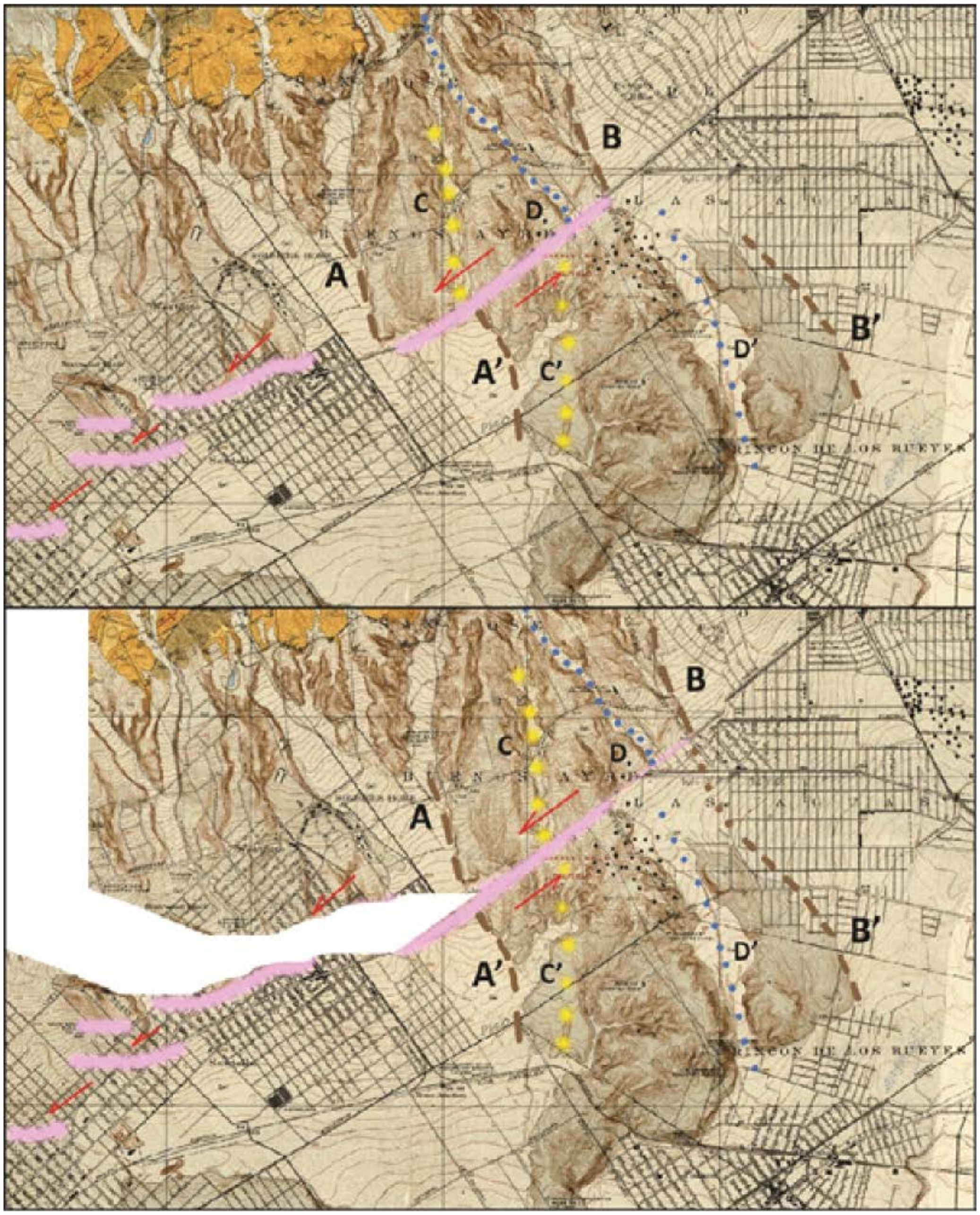

Figure 33 – Top: Geologic map (Hoots, 1931) with possible correlating alluvial drainages and margins; Bottom: Aligned alluvial drainages and margins after approximately 1.2 km of backslip along SMFZ. (figure prepared by J. Trieman

the western and eastern lateral margins, along with some of the major canyon drainages, it appears plausible the Cheviot Hills are left-laterally offset by the SMFZ. By moving the northern block approximately 1,200 meters northeast relative to the southern block, these features appear to line up (Figure 33).

Scarp heights range from 5 to 15 meters, but are not consistently south-facing like those to the west. Figure 34 depicts a topographic profile drawn across the main scarp near Sepulveda Canyon and a second profile drawn across the Santa Monica Boulevard scarp in the Cheviot Hills. The western profile shows a south-facing scarp typical for Segments 1 and 3, while the eastern

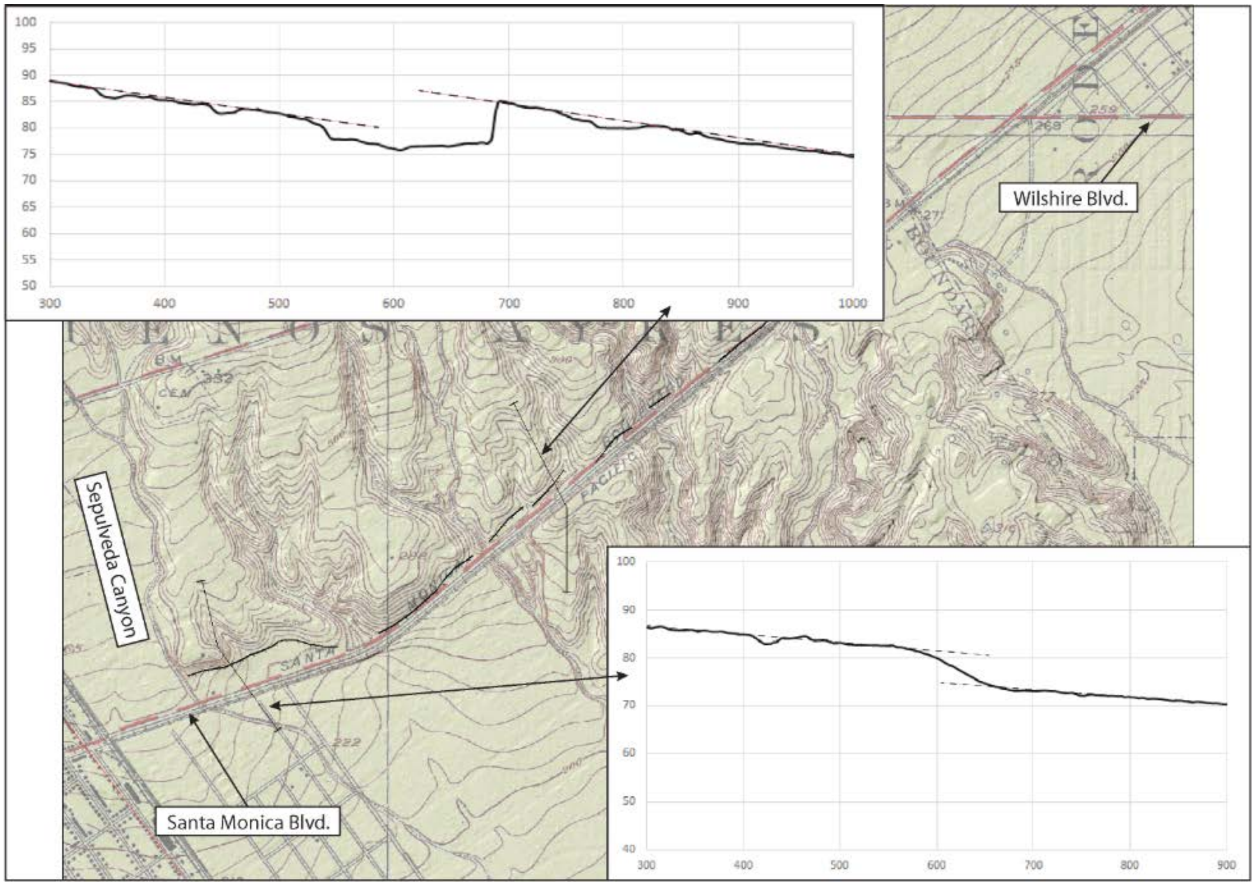

Figure 34 - Topographic profiles looking east across two different scarps along Santa Monica Blvd. in the Cheviot Hills. Scarp on the west is south-facing and ~2 m high. Scarp to the east is ~2.5 m high and north-facing. Profiles are 5x vertically exaggerated. Black lines with tick marks are geomorphic scarps. Base imagery is the LA County lidar hillshade with a 315° illumination angle; topographic base map is 1925 USGS 6' Sawtelle quadrangle map.

profile depicts what appears to be an anomalous north-facing scarp. This inconsistency is plausibly explained by left-lateral offset of the highly dissected older alluvium, which transports alluvial surfaces of different elevations laterally along the fault. Similarly, lateral motion of a terrain with a dense drainage network like the Cheviot Hills will produce offset streams that appear both left- and right-deflected. The Santa Monica Boulevard scarp appears to be affected by erosion at its easternmost end, where it changes orientation again and trends roughly N25°E at the southern end of the Los Angeles Country Club. This northern scarp may represent a splay of the main SMFZ in this area. Several studies documented inactive faults in the vicinity of, and subparallel to, this northern scarp suggesting the erosion may in part be fault-controlled. Moving east the northern scarp appears to be truncated along the eastern margin of the Cheviot Hills (i.e. the WBHL) near El Rodeo School (Locality 18 on Figure 14); however, to the south the Moreno Creek channel is deflected at the eastward projection of the main Santa Monica Boulevard scarp into the Beverly Hills alluvial plain (Plate 2).

Subsurface investigations along this segment confirm the scarp along Santa Monica Boulevard and the observed deflected drainages are related to faulting. Several studies that were previously discussed in this report have interpreted numerous fault splays along this scarp, forming a zone up to 100 meters wide. Many of the faults encountered within this zone were determined to be inactive within Holocene time; however, two notable investigations located at either end of Segment 4 revealed fault strands, which are active (AES, 2015a,b; Metro, 2017). Thus, it appears that although several faults encountered within this fault zone appear to be inactive, there are documented active strands, and it is reasonable to infer these strands are roughly continuous along the scarp. This fault zone configuration is similar to the Hollywood Fault to the northeast where the zone consists of a roughly continuous active fault flanked by demonstrably inactive strands that are within 60 to 100 meters from the main active fault. The northern splay through the Country Club leading toward El Rodeo School is not recommended for zoning based on the findings of the Wilshire Boulevard boring/CPT transect where the fault was interpreted to be inactive during Holocene time. Should additional data become available, this segment should be reevaluated to determine the width of the fault zone and the recency of movement along the faults.

Segment 5

This segment is located east of the WBHL and entirely within the Beverly Hills alluvial plain. While there are no apparent well-expressed geomorphic scarps suggestive of faulting, there is an apparent deflection in the Moreno Creek channel at the northern end of Beverly Hills High School, which may be related to faulting as it is in line with the Santa Monica Boulevard scarp. Additionally, the surface projection of the fault encountered in the Metro (2017) investigation (Figure 19) and the groundwater barrier identified by Petra (Figure 21) are in good alignment with the main scarp and apparent stream deflection suggesting the SMFZ extends at least this far into the Beverly hills alluvial plain. From here, the fault may continue through the subsidence anomaly identified by Petra (M. Schultz, pers. comm., 2014) and connect in some way with the North Salt Lake Fault, which forms the southern structural boundary of the Hollywood Basin (Hildenbrand *et al.*, 2001) and is also associated with a zone of differential subsidence described by Hill *et al*. (1979). This model is plausible, but it is noted there is a lack of geomorphic evidence of recent movement and no subsurface data at this time supports this connection. Should additional data become available supporting the continuity of this fault system, a re-evaluation of this portion of the fault zone would be warranted.

Potrero Canyon Fault East

As part of his regional tectonic evaluation of the study area, KGS (2016) postulated that a youthful left-lateral strike-slip fault is developing in the southern Cheviot Hills, which they referred to as the Potrero Canyon Fault East (PCFE). They note evidence for the existence of this fault includes a weakly defined alignment of saddles and swales that appear to coincide with drainage gradient changes, the fan apex location of the younger BCWD unit on the western side of the Cheviot Hills, and a significant drop in terrace elevations to the south across the alignment (Figure 35). KGS additionally observed the trend of these geomorphic features is generally aligned with the overall trend and location of the 2001-2003 seismicity sequence (Figure 26). On their 2016 map, KGS classifies the PCFE as an active fault; however, Miles Kenney concludes the fault, particularly in the east, has not likely ruptured to the surface (M. Kenney, pers. comm., 2016).

The evidence presented for the existence of this fault is sparse and not wholly supported. For example, the postulated existence of the fault through the Cheviot Hills is based on the difference in elevations between two terrace surfaces; however, no data is yet provided to demonstrate these terraces are the same age and were once continuous. Based on this model, the PCFE may exist, and may indeed be active, but additional data is needed to confirm this model. Should additional data become available supporting the existence and activity of the PCFE, it should be evaluated to determine if it poses a surface rupture hazard.

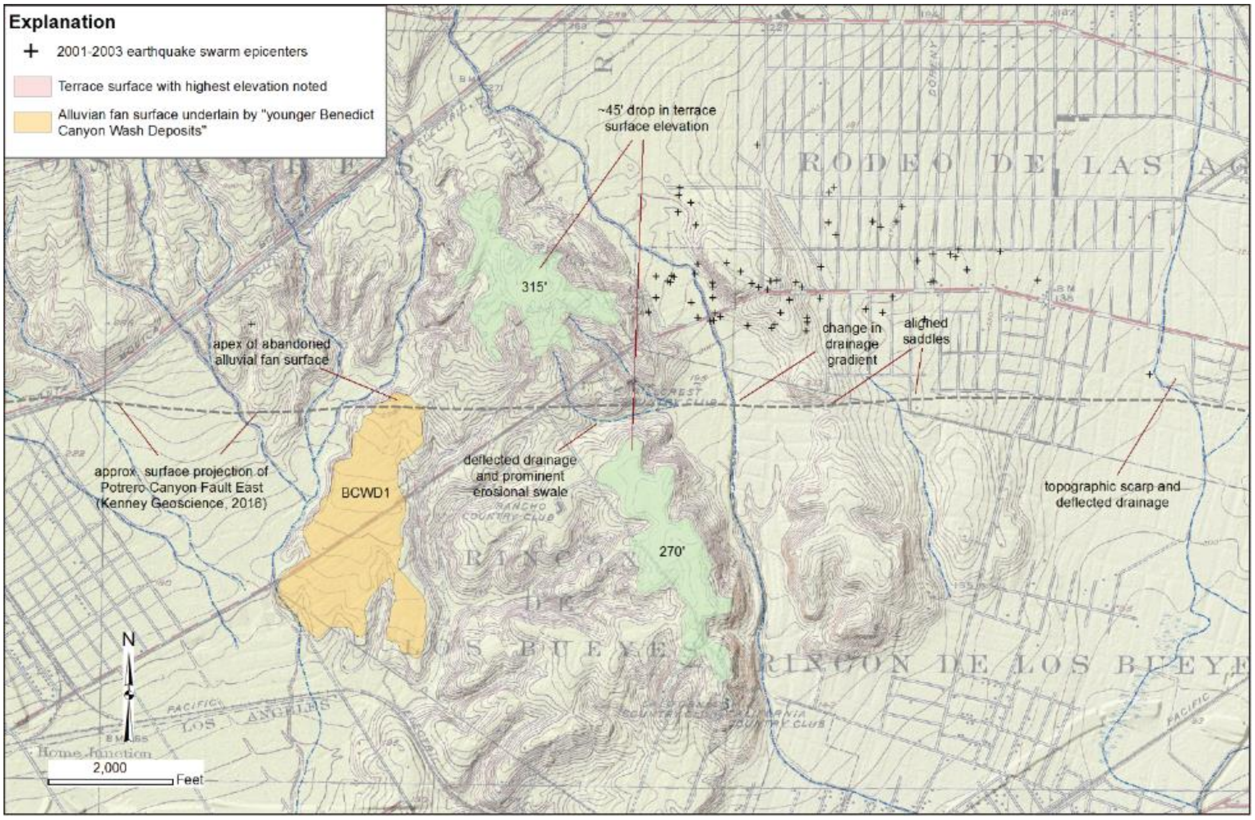

Figure 35 - Potential geomorphic evidence supporting the postulated Potrero Canyon Fault East of Kenney Geoscience (2016) through the Cheviot Hills. Topographic base map is 1925 Sawtelle and 1926 Hollywood 6' quadrangles. Contour interval is 5 feet.

NEWPORT-INGLEWOOD FAULT ZONE

Bryant (1985) mapped a series of active fault strands trending northwesterly through the Baldwin Hills and extending just over 1 km into the alluvium of Ballona Gap (Plate 1). North of, and in-line with, these faults are two subparallel east-facing scarps observed in the Los Angeles County 3-meter lidar hillshade (LARIAC, 2006) ranging from 1.5 meters (western) to over 2.5 meters high (eastern) (Figure 36). These scarps appear to roughly coincide with the western boundary of the historic Ballona wetland habitat (Figure 25) suggesting they are associated with the Newport-Inglewood Fault Zone, which forms a fault-related groundwater barrier causing elevated groundwater levels to the east. They also approximately correspond with the "Inglewood Fault" and "West Pico Fault" of Erickson and Spaulding (1975) (Plate 1). Of the two subparallel slope breaks noted on Plate 2, the easternmost is more directly aligned with the eastern Ballona Gap scarp and also coincides with the historic boundary of the Ballona wetlands. Therefore, it was inferred to represent a continuation of the NIFZ fault zone to the south. Because the western slope break is more oblique to the western Ballona scarp and does not appear to be associated with any marked changes in groundwater levels, it is not interpreted to be associated with active faulting.

WEST BEVERLY HILLS LINEAMENT

The informally named West Beverly Hills Lineament (WBHL), first named and described by Dolan and Sieh (1992), is a north-northwest trending series of relatively continuous east-facing escarpments separating elevated older alluvium of the Cheviot Hills to the west and the gently

Figure 36 - Topographic profile across two east-facing scarps in the Ballona Gap. Scarp on the west is ~1.5 m and scarp on the east is ~2 m. Profile is 10x vertically exaggerated. Base imagery is LA County lidar hillshade with 45° illumination angle; topographic base map is modern USGS 7.5' Beverly Hills quadrangle map.

sloping, younger alluvial plain to the east. Heretofore, the dominant explanatory theory for this feature was that it represented the northernmost extension of the NIFZ because of its rough alignment with the trend of the overall fault zone. However, Leighton Consulting, Inc. (2012a,b,c) excavated a fault trench and drilled a boring/CPT profile across this topographic scarp and found no evidence of significant faulting in the Quaternary sediments. KGS (2016) postulated that the sediments underlying the Cheviot Hills began to be folded and uplifted about 1 Ma due to east-west compressive stresses caused by left-lateral motion along the SMBF and the hypothesized PCFE, which shunted this crustal block against the northern strands of the NIFZ to the east. As the region was elevated, several drainages developed and incised the hills and the alluvial plain, including Moreno Creek, which eroded through the Cheviot Hills creating a water gap between the Cheviot Hills to the west and the lower, southeastern Cheviot Hills to the east. As noted earlier, the data from several studies and evaluations suggests it is more likely the northernmost NIFZ is located farther east, most likely along the eastern margin of the southeastern Cheviot Hills where it creates a groundwater barrier and forms the western edge of a historic wetlands complex (see Figure 25).

RECOMMENDATIONS

Recommendations for establishing Earthquake Fault Zones are based on the criteria of "sufficiently active" and "well-defined" (Bryant and Hart, 2007).

The principal traces of the **Hollywood, Santa Monica, and Newport-Inglewood Fault Zones** as shown on Plate 3 are recommended for zoning as they are well-defined and there is sufficient evidence to conclude they are active. The northern terminus of the previous zone boundary for the NIFZ established by Bryant (1985) should be widened and extended to encompass the newly identified fault traces as depicted on Plate 3. The Potrero Canyon Fault East of KGS (2016) is not recommended for zoning at this time. No zone is recommended for the West Beverly Hills Lineament as it does not appear to be a fault-related feature.

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AIR PHOTOS AND DIGITAL IMAGERY REVIEWED

Fairchild Aerial Surveys	Flight 113	1927 b/w Stereo-pair	scale 1:18,000 vertical	Frames:17 – 19, 24 – 28, 36 – 40, 58 – 59, 75 – 81, 121 – 128
Fairchild Aerial Surveys	Flight C-300	1928 b/w Stereo-pair	scale 1:18,000 vertical	Frames: K21 – K23, K44 – K47, K73 – K74
Spence Aerial Photography	E-3455-17b	02-28-1932	Oblique	"Huntington Palisades and Mouth of Santa Monica Canyon"
"	E-2938-18	1922	Oblique	"Westwood north of Pico at Westwood Blvd."
"	E-2940	1922	Oblique	"Westwood from Rancho Club"
"	E-7263-17b	1924	Oblique	"Huntington Palisades & Santa Monica Canyon"
"	E-6886	Nov. 1925	Oblique	"Westwood"
"	E-965	12-10-1926	Oblique	"North of Santa Monica Blvd. between Beverly Hills Fox Studios"
"	E-3005	10-24-1929	Oblique	"Westwood, N. of Santa Monica Blvd."
"	E-3975	03-18-1933	Oblique	"Sawtelle – looking east from Centenella & Santa Monica"
"	E-12676-30	11-24-1946	Oblique	"N.E. from Baldwin Hills at 1000 Gardens"
"	E-12552-30	10-11-1946	Oblique	"E from Rodeo Rd. & Ballona Creek"

Additional Imagery:

NAIP (National Agriculture Imagery Program): NAIP imagery from 2012 and 2016 was used as a reference for interpretation of fault-related lineaments and topography. A county-wide image of Los Angeles was used to locate features identified in historical imagery and digitally geo-reference geotechnical report maps. The images were viewed within the GIS platform (ArcGIS) and interpretation done directly on screen.

Los Angeles Region Imagery Acquisition Consortium: proprietary dataset, LiDAR data acquired 2006. (1.7 m DEM) http://planning.lacounty.gov/lariac

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