Structural and stratigraphic evaluation of the Century City – Cheviot Hills area, California

Report Prepared For:

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Job Number: 723-11

Report Date: JULY 8, 2014

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APPENDIX C – ATTACHED REPORTS

1. Earth Consultants International (ECI), 2012, Soil-stratigraphic studies for Beverly Hills High School, 241 Moreno Drive, Beverly Hills, California; report prepared for Hill Farrer & Burrill, LLP, report dated April 10, 2012.

2. Earth Consultants International (ECI), 2012, Supplemental report on the age of the sediments underlying the Beverly Hills Hih School and vicinity using soil-stratigraphic techniques, 241 Moreno Drive, Beverly Hills, California; report prepared for Hill, Farrer & Burrill, LLP, report dated December 21, 2012.

3. Helms, J. (High Desert Consulting, Inc.), 2012, Soil stratigraphy and relative age determinations for a fault rupture hazard assessment, 10,000 Santa Monica Boulevard, Los Angeles, California; report prepared for Geocon, Inc., report dated August 17, 2012.

4. Helms, J. (High Desert Consulting, Inc.), 2013, Soil stratigraphy and relative age estimates for a fault rupture hazard investigation at Westfield Century City Mall, 1801 Avenue of the Stars, 10250 Santa Monica Boulevard, and 1930 Century Park West, Century City – Los Angeles, California; report prepared for Geocon, Inc., report dated July 26, 2013.

5. Soil Tectonics, 2012a, Late Pleistocene Soil Development on Isolated Terraces at Beverly Hills, California; report prepared for Leighton Consulting, Inc., and Kenney GeoScience, report dated May 12, 2012.

6. Soils Tectonics, 2012b, Pedochronological Report for Beverly Hills High School, Beverly Hills, California, report prepared for Leighton Consulting, Inc., report dated May 12, 2012.

7. Legg Geophysical Inc., 2012a; Beverly Hills High School, Active Fault Investigation; report prepared for Beverly Hills High School, report dated January 27, 2012.

8. Legg Geophysical Inc., 2012b, Beverly Hills High School, Independent Review of Metro Century City Area Fault Investigation Report Appendix D (*from Parsons 2011*), report prepared for Beverly Hills High School, report dated May 10, 2012.

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Subject: **Structural and stratigraphic evaluation of the Century City - Cheviot Hills area, California**

This is the final report requested by the Beverly Hills Unified School District. The report provides a structural and stratigraphic analysis of the Cheviot Hills especially that portion covering Century City and the western side of the City of Beverly Hills including the Beverly Hills High School campus and El Rodeo campus. There are several detailed site investigations in this area that have been completed or are ongoing. The intent of the report is to allow consideration of this emerging geologic information within an overall site and regional context. Unless stated otherwise, the findings provided in this report supersede those provided in the Kenney Geoscience (KGS) reports dated May 2, 2011, July 18, 2012 and May 15, 2013.

This report focuses primarily on the stratigraphy and structure of the Century City area, and how a detailed analysis can shed light on the neotectonic structures of the area. The report makes numerous conclusions based upon the available research and data. The ongoing site investigations in the area will continue to provide additional data that will require subsequent amendment to adjust the findings and conclusions presented in this report.

This report is not to be considered a fault investigation report satisfying the fault hazard investigation criteria provided in Byrant and Hart (2007) for the Alquist-Priolo State of California law. Instead, it is intended to assist future studies in developing a reasonable scope of work partially based on the proposed stratigraphy and fault zone delineations provided herein. An attempt was made to correlate numerically dated soils across the site to provide future investigators an estimate of the age of the units underlying their site, the approximate magnitude of fill or cuts in the area, and the general location and style of faulting that may be encountered.

The quality and density of subsurface data utilized in this report varies across the site. Future investigators are cautioned to review the report findings with this consideration. All of the data utilized in this report are public documents and can be utilized to provide additional interpretations. Most of the reports providing numerical soil ages are provided in this report (Appendix) to assist the reader is acquiring that information.

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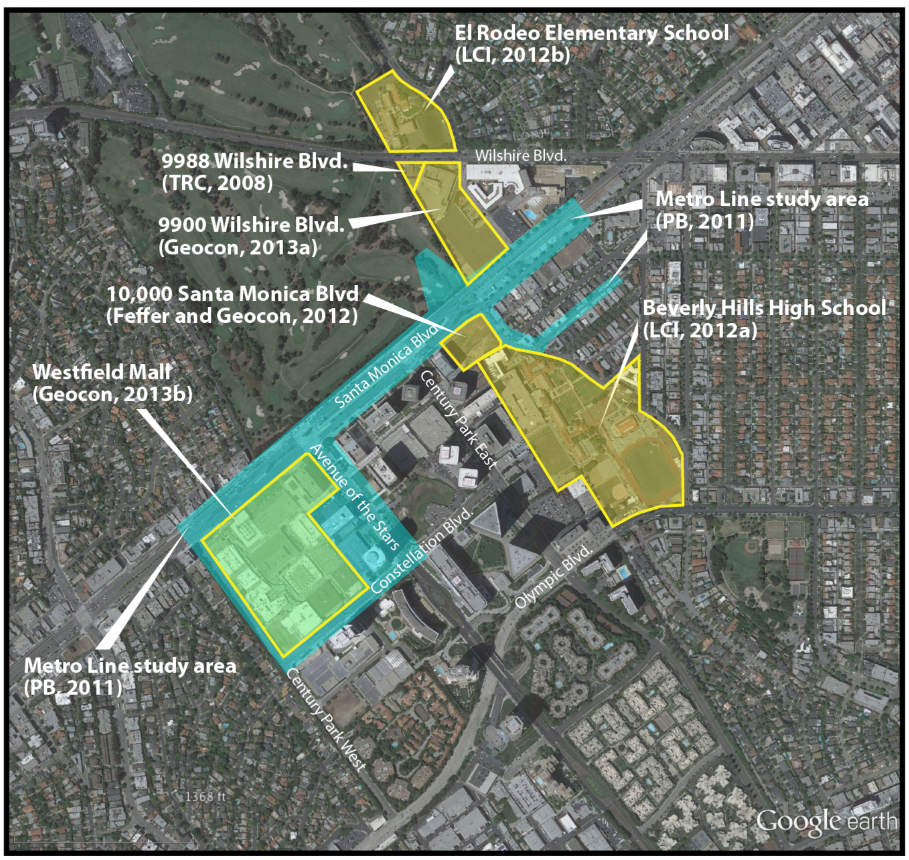
1.0 INTRODUCTION

Kenney GeoScience (KGS) was retained by the Beverly Hills Unified School District to provide a geologic (structural and stratigraphic) evaluation of the Century City/Cheviot Hills area since 2011 utilizing all of the newly available data. Numerous recent site-specific geologic studies have been completed or are underway by various parties within the Century City/Cheviot Hills area (Figure 1). The Los Angeles County Metropolitan Transportation Authority (Metro or MTA) completed a fault study that included potential (proposed) subway station sites and the Beverly Hills High School area conducted by Parsons Brinkerhoff (Parsons, 2011). The Beverly Hills Unified School District has completed a fault investigation study of the Beverly Hills High School (LCI, 2012a) and a preliminary fault evaluation for the El Rodeo K-12 School (north of the proposed eastern Santa Monica subway station site; LCI, 2012b). Recent fault investigation studies by private parties have been conducted at the Westfield Mall (Geocon, 2013b) and 10,000 Santa Monica Boulevard (Feffer and Geocon, 2012). Groundwater monitoring data and associated borings were also utilized from 9988 Wilshire Boulevard site (TRC, 2008). Geotechnical borings conducted by MACTEC and included in Geocon (2013a) were utilized for the 9900 Wilshire Boulevard property. Geocon (2014) has recently completed a fault investigation at 9900 Wilshire Blvd.; however, these data were not utilized in this report due to the recent release. Shannon and Wilson (2012) completed a report providing an independent review of existing "faulting" data in Century City area dated March 8, 2012.

Figure 1: Location of subsurface geologic studies in the Century City area utilized in this report.



1.1 Purpose and study context

The general purpose of this analysis is to establish a local geologic context based on evaluation of site specific data being generated by all parties using standard geomorphic, structural and stratigraphic methods of analysis. These data were utilized to provide a simplified stratigraphy and stratigraphic history, estimate the age of deposition of designated units, and attempt to correlate marker beds across the site. The study also provides a characterization of various fault zones that are interpreted to exhibit a "zone of faulting" with similar styles or modes of displacement across numerous strands.

The immediate purpose of this study is to better understand potential fault surface rupture hazard in the Century City area, and particularly in regard to how it might affect local schools (El Rodeo K-12, Beverly Hills High School). Additionally, to evaluate potential faulting issues associated with the proposed Metro subway station sites along Santa Monica Boulevard and Constellation Boulevard (Figure 6). A subsequent report (in preparation) will provide findings regarding regional structure and tectonic kinematics.

The reader is referred to Gath and Buresh (2014) for a thorough discussion regarding the history of regulatory agencies, the scientific community, and developers including the Los Angeles Metro Authority in regards to current understandings of potential fault surface rupture in Century City and Cheviot Hills. Their report provides an understanding regarding the impact findings provided by the scientific community, the California Geological Survey and United States Geological Survey have had in understanding potential faulting in the study area and how their findings may have affected recent fault investigations locally. In addition, their report discusses numerous impacts on future developers and City regulatory agencies (i.e. City of Beverly Hills and Los Angeles) due to the findings of both local geologic fault investigation reports (i.e. Parsons, 2011), and fault maps by the California Geological Survey also adopted by the United States Geological Survey identifying "active faults" in a region where no active faults had been positively identified.

1.2 Scope of study

Kenney GeoScience (KGS) was requested to perform a geomorphic, structural and stratigraphic evaluation of the eastern Santa Monica Fault Zone and the West Beverly Hills Lineament in the Cheviot Hills area of Century City and Beverly Hills, California, based on an integrated review of older published maps and data and the recently completed investigations. The immediate purpose of this study is to better understand potential fault surface rupture hazard in the Century City area, and particularly in regard to how it might affect local schools (El Rodeo K-12, Beverly Hills High School). In addition, the review covers the proposed Metro subway station sites along Santa Monica Boulevard and the proposed Metro subway station site on Constellation Boulevard (Plate KGS-FM-1). A subsequent report (in preparation) will provide findings regarding regional tectonic structure (kinematics) with an emphasis on potential seismic hazards in the City of Beverly Hills.

1.3 Disclaimer regarding report conclusions

This study should not be considered a fault Investigation study under the guidelines of the State of California Fault Hazard Zoning Act of 1972 (Bryant and Hart, 2007). Instead, the findings in this report are recommended as a tool to assist future development in the Century City area by providing a regional consistent stratigraphic foundation (including approximate age), for future investigations into the character and location of faulting. Hence, findings provided herein regarding fault activity are not be to considered as satisfying State of California Fault Hazard Act guidelines and are only provided as a guide regarding their potential activity.

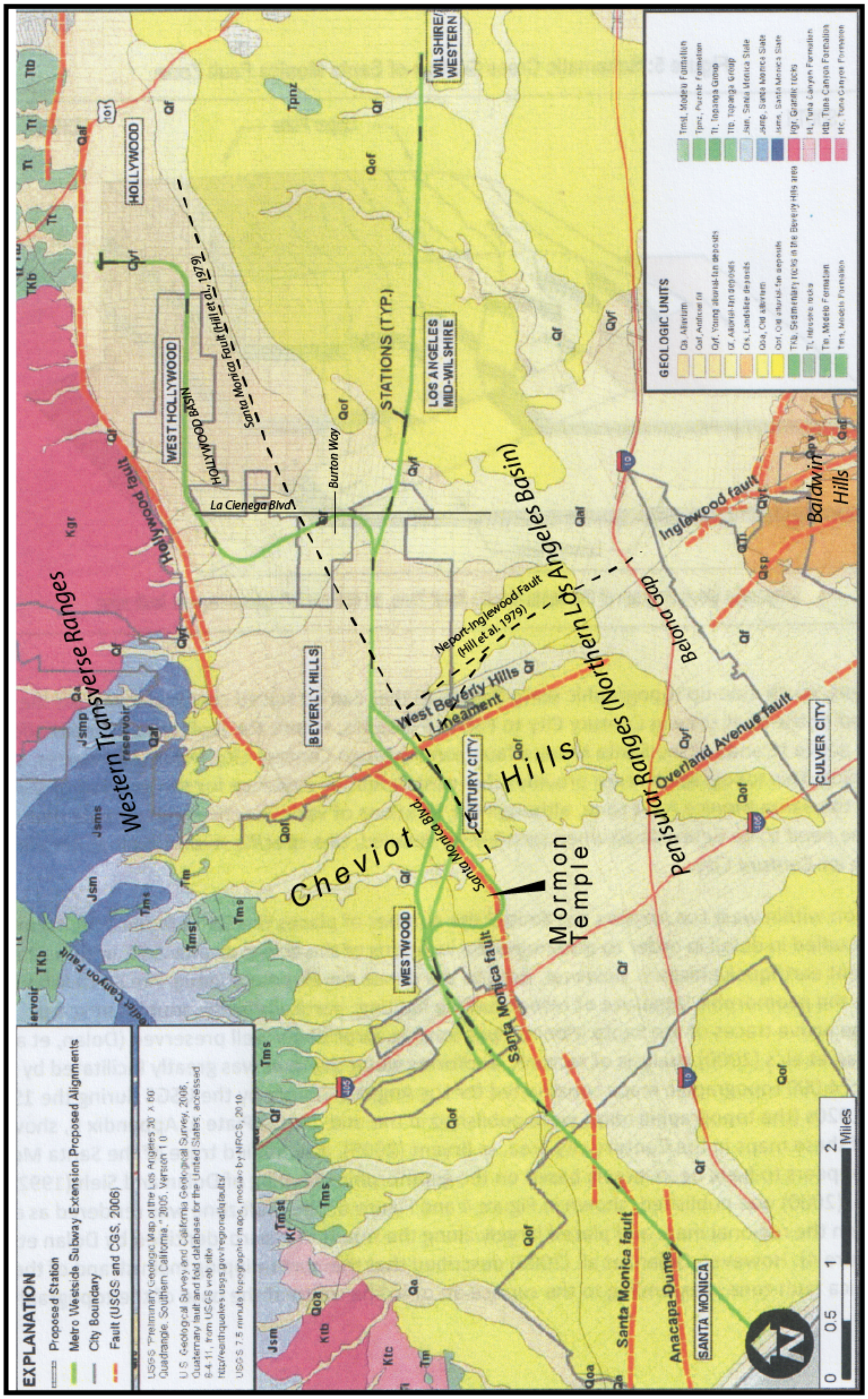
2.0 REGIONAL FAULT ZONES IN CENTURY CITY AND CHEVIOT HILLS AREA

The Century City/Cheviot Hills area has long been a subject of great geologic interest because of its location near numerous fault zones (Santa Monica, Hollywood, San Vicente [blind], and Newport-Inglewood), variations in sedimentation and deformational history since the Miocene, which has involved reactivation of some older faults (Figure 2; Yerkes et al., 1965; Yerkes and Lee, 1979, Wright, 1991; Yeats and Beall, 1991). The complex geologic history is primarily due to its location at the boundary between the Western Transverse Ranges located locally north of the Santa Monica-Hollywood Fault Zones and Peninsular Ranges located to the south (Figure 2). This boundary has experienced varying styles of tectonic deformation associated with Miocene extension that predates development of the Los Angeles Basin, followed by the development of the San Andreas Fault System, which continues today. This deformation allowed for the structural and stratigraphic traps associated with numerous oil fields in the northern Los Angeles Basin (Wright, 1991; California Oil and Gas Fields – third edition, 1991).

Faulting in the region is remarkably complex as various faults were active at different times under varying tectonic stress regimes to become inactive over time, or re-activated to accommodate a new style of tectonic stress. In addition, some faults reach the surface and others are blind (do not reach the surface), are associated with folding and faulting, exhibit multiple strands that were active at different times, are so deep that their actual presence are difficult to evaluate, and others have migrated laterally over time. All of these factors result in difficulties evaluating current seismic hazards associated with these faults. For example, it is possible that the currently active compressional faults are blind and so deep that they have not yet been positively identified. For example the proposed Los Angeles Fault from Schneider, et al., (1996). The location and activity level of many of these fault systems remain poorly understood; hence, insufficient data exists to fully evaluate seismic hazard risk with any great certainty.

In terms of fault surface rupture hazard (faults in or near the site), and based on existing scientific publications, the site, which includes Century City and the City of Beverly Hills in the region of Beverly Hills High School is potentially affected by two fault zone systems. These include the approximate east-west trending Santa Monica Fault Zone locally located approximately along Santa Monica Boulevard, and the North-northwest trending Newport-Inglewood Fault Zone confirmed to be located in the Baldwin Hills south of the Cheviot Hills but may occur east of the Cheviot Hills (Figure 2). These fault zones are discussed in the next two sections.

Figure 2: Regional fault and geology map of the northern Los Angeles Basin depicting Metro Westside Subway Extension Proposed Alignments. Modified from Parsons (2011; Figure 4)



2.1 Santa Monica Fault Zone

The Santa Monica Fault Zone is complex in terms of location (numerous strands), age (most strands are considered inactive) and nomenclature in the literature. Since the 1960's, many scientific authors simply drew a line representing the "Santa Monica Fault" as extending from the Pacific Ocean in the City of Santa Monica eastward to connect with the eastern Hollywood Fault, then the Raymond fault further east near the San Gabriel Mountains (Yerkes et al., 1965; Yerkes and Lee, 1979; Yeats and Bealle, 1991). It should be pointed out that in many of these studies the Hollywood Fault Zone was included as part of the lager "Santa Monica Fault Zone", which was typically identified as the primary structure separating the Western Transverse Ranges to the north and the Peninsular Ranges to the south. Crook and Proctor (1991) evaluated the Santa Monica – Hollywood Fault Zones and provided various models suggesting where late Pleistocene fault strands may occur associated with these fault systems.

Various strands of the complex Santa Monica fault zone has been mapped through Century City/Cheviot Hills in the general area Santa Monica Boulevard and the southern Cheviot Hills; notable publications and general findings include:

- Yerkes et al., (1965) on region fault maps show the Santa Monica Fault Zone extending along the north edge of the Beverly Hills and North Salt Lake oil fields which places the fault within the central Cheviot Hills (Santa Monica Boulevard).

- *Erickson and Spaulding (1975)* placed the Santa Monica Fault as a north dipping, NEE trending zone along approximately the northern limits of the Beverly Hills West Oil Field, which approximately coincides with the current Santa Monica Boulevard (Figure 5). This report indicates that this strand of the Santa Monica Fault (same fault as Wright, 1991 Santa Monica Fault North) extends to the un-faulted base of the upper Pliocene-Pleistocene age sediment contact at an approximate depth of 500 feet east of the Cheviot Hills in the general region of La Cienega Boulevard and Burton Way (Figure 2).

- *Hill et al. (1979)* based on primarily groundwater data indicate that the Santa Monica Fault occurs near Constellation and Santa Monica Boulevards in Century City and extends toward the northeast along the southern boundary of the Hollywood Basin (Figures 2 and 5). These data suggest that fault related groundwater barriers extend into Pleistocene age sediments.

- *Crook and Proctor (1992)* mapped the Santa Monica Fault in the Century City essentially along Santa Monica Boulevard based on topographic scarps and fault trenching in the VA Hospital property. Mr. Richard Proctor (personal communication) extended the fault eastward into the Cheviot Hills along Santa Monica Boulevard based on his geomorphic evaluation of the topographic contours of Hoots (1931) geologic map.

- *Wright (1991)* based on oil boring data identified a fault he named the Santa Monica Fault North that through the Cheviot Hills that dips northward, and trends parallel to Santa Monica Boulevard (Figure 5). He identifies the fault at a depth of approximately 1100 feet dipping to the north and with a northeast trend nearly parallel with Santa Monica Boulevard. Wright indicates that the fault does not likely offset Pliocene age sediments. If this fault plane is projected to the surface it coincides closely with the location of Santa Monica Boulevard in Century City.

- *Dolan and Sieh (1992)* performed geomorphic mapping and identified a series of escarpments they referred to as scarps along Santa Monica Boulevard in the Cheviot Hills between the Mormon Temple and Century City (Figure 3; also see Dolan et al., 2000a). They attributed the scarps due to left-lateral reverse (oblique) faulting on the Santa Monica Fault Zone they extend from the VA Hospital eastward to terminate at the West Beverly Hills Lineament.

Wright (1991) performed a comprehensive study evaluating oil well data throughout the Los Angeles Basin and identified numerous fault zones in the northern Los Angeles Basin, most of which do not appear to offset or deform Pleistocene age sediments. These fault systems include the Santa Monica Fault North and South (Figure 5). Wright (1991) utilizing data from Crook and Proctor (1991) and his own analysis also identified places of possible Pleistocene surface faulting in the general region of the Santa Monica Fault Zone from the Pacific Ocean in the City of Santa Monica to the Mormon Temple in the western Cheviot Hills (Figure 5). Wright (1991) simply referred to this fault system as the Potrero Canyon Fault based on a fault exposure and presumed fault scarps in Pleistocene fan terraces near Potrero Canyon on the Pacific Coast. This fault zone occurs in a region where Wright (1991) shows the north dipping Santa Monica Fault South at least a kilometer deep (Figure 5).

Dolan and Sieh (1992) performed a geomorphic fault evaluation of this area and delineated a series of left-stepping faults in the same general location as Wrights (1991) Potrero Canyon Fault Zone. In addition, Dolan and Sieh (1992) identified “fault scarps” associated with the same fault system along Santa Monica Boulevard in the Cheviot Hills from the Mormon Temple to their West Beverly Hills Lineament (Figures 2 and 3). Dolan and Sieh (1992), and in fairly good agreement with Crook and Proctor (1991) referred to this system of fault scarps as the Santa Monica Fault Zone, which presumably they believed represent recent fault splays of the older and deeper Santa Monica Fault South of Wright (1991); however the relationship between the faults associated with the surface scarps and underlying Santa Monica Fault South of Wright (1991) was not explained.

In terms of fault activity, prior to 2012, the closest paleoseismic fault study conducted on the Santa Monica Fault Zone was at the West Los Angeles Veterans Administration Hospital site located approximately 2 miles west of Century City by Dolan et al. (2000a) that determined that the Santa Monica Fault Zone is active (Figure 3). However during this study a primary basal fault associated with the Santa Monica Fault Zone that presumably would accommodate oblique left-lateral reverse deformation was not positively identified. Currently, the State of California Geologic Survey (CGS) under the Alquist-Priolo Fault Hazard Zones has not published Fault Hazard Zone maps for the Santa Monica Fault Zone, however they do consider it active. We were informed that the City of Los Angeles will be releasing fault hazard zone maps for numerous faults within their jurisdiction in the coming weeks. LCI (2012a) and Geocon (2013b) determined that the primary zone of faulting (Fault Zone F for KGS, 2013 and this study; Figure 7) is inactive. The area of these studies are actually located south of the fault scarp identified by Dolan and Sieh (1992) which coincides with Fault Zone A of Figure 17. The names and general location of fault zones utilized in this study is provided in a later section of this report.

Figure 3: Local fault and geology map of the eastern Santa Monica Fault Zone depicting Metro Westside Subway Extension Proposed Alignments. Modified from Parsons (2011; Figure 6)

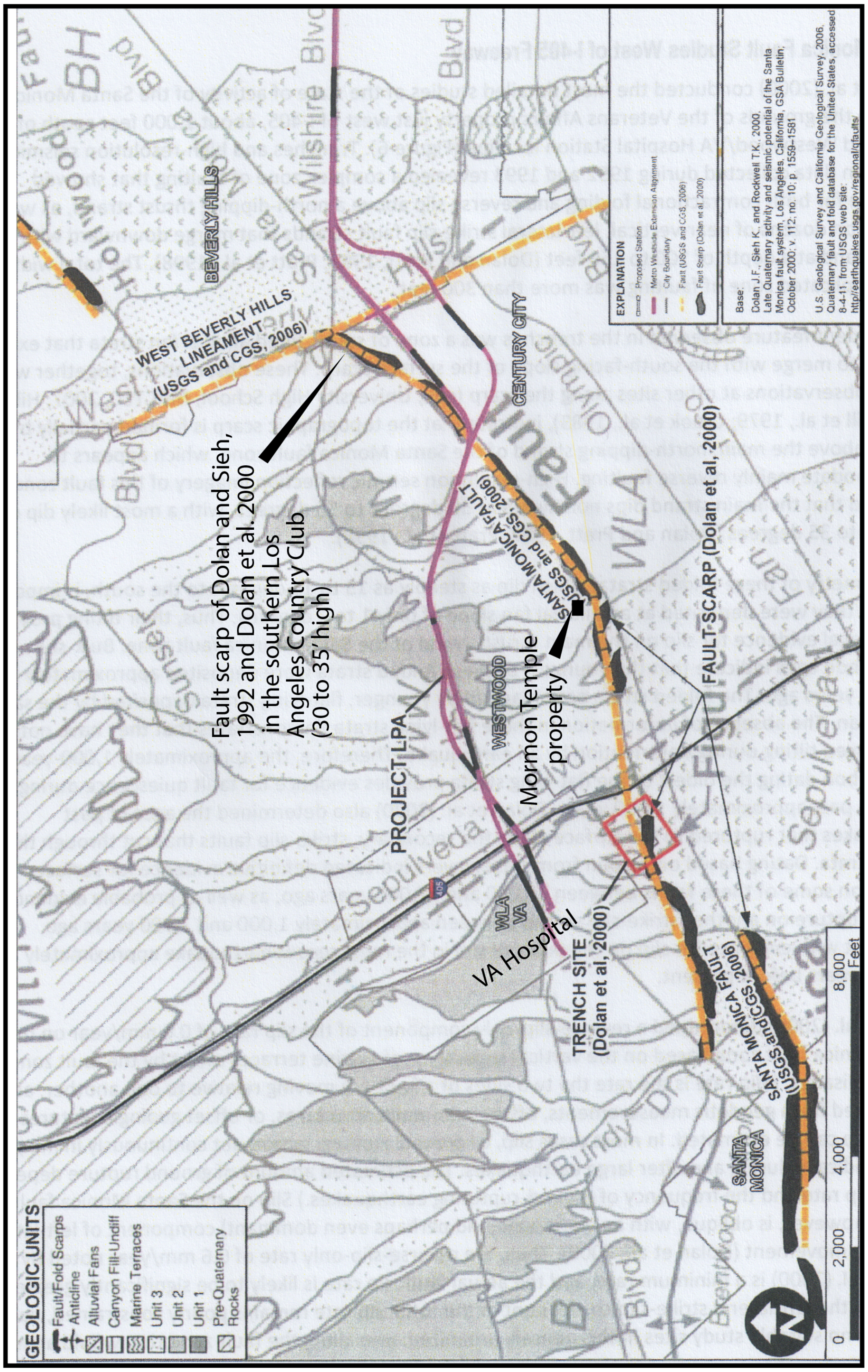


Figure 4: Santa Monica Fault Zone sections as discussed in this report.

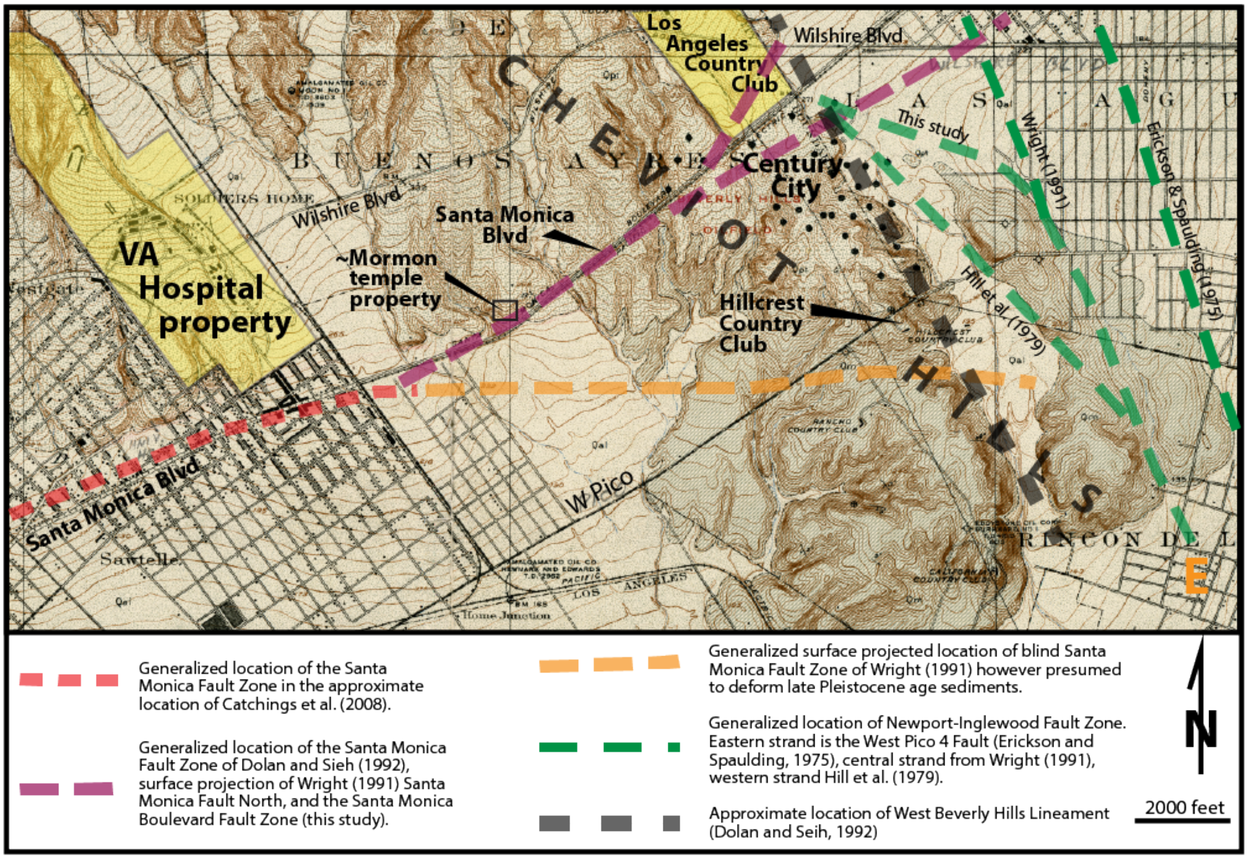
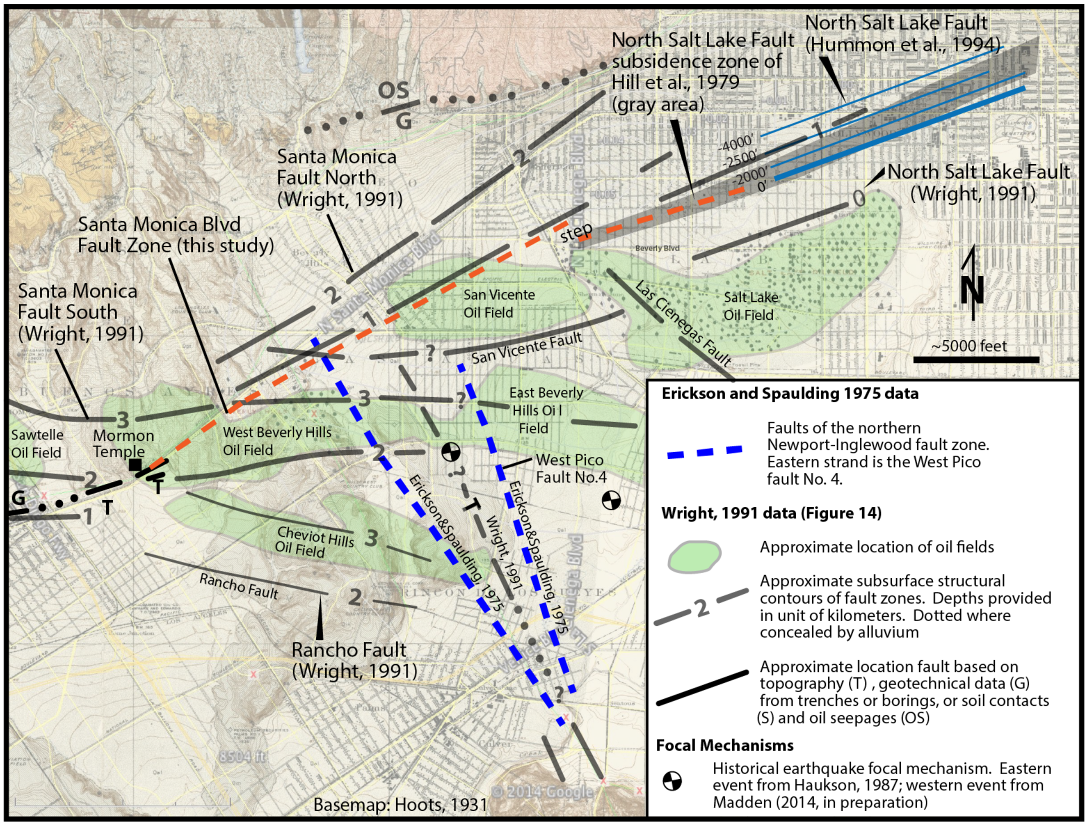


Figure 5: Regional fault and oil field location map of the Cheviot Hills-Northern Los Angeles Basin.



2.2 The Newport-Inglewood Fault Zone

Possible fault strands associated with the Newport Inglewood Fault Zone proposed by Erickson and Spaulding (1975; eastern strand), Wright (1991; central strand) and Hill et al (1975; western strand) are shown as green on Figure 4. Erickson and Spaulding (1975) suggest that their West Pico Fault No.4 is a strand of the Newport-Inglewood Fault Zone due to its strike, sense of offset, and that this fault likely offsets Pleistocene sediments identified by a groundwater barrier. Wright (1991) and Erickson and Spaulding (1975) and Wright (1991) suggest that strands of the Newport-Inglewood Fault Zone provide the structural boundary between the West and East Beverly Hills Oil Field. Poland et al. (1959) provide stratigraphic and groundwater data suggesting that strands of the Newport-Inglewood Fault Zone extends as far north as the approximate center of Belona Gap. They also indicate that these fault strands do not offset their “50-foot gravels” which are late to latest Pleistocene in age. Hauksson (1987) provides seismicity data (focal mechanisms) interpreted to suggest that strands of the Newport-Inglewood Fault Zone extends north of Bellona Gap and east of the Cheviot Hills.

Tieje (1926) identified a northwest trending anticline in the Baldwin Hills (see Inglewood Anticline in Tsutsumi et al. 2001) active during the Pleistocene developed due to motion on the Newport-Inglewood Fault Zone. KGS (2012) identified a similar antiform in terms of trend and age in the Cheviot Hills approximately on strike with the antiform identified by Tieje (1926) in the Baldwin Hills. Hummon et al. (1994) mapping of the base of Quaternary gravels in the region also identified a antiformal structure that trends toward the northwest from approximately the Baldwin Hills to the southern Cheviot Hills. Hoots (1931) based on tilted beds in the Cheviot Hills (southern portion likely based on the location of strike-dip symbols) were deformed during the Pleistocene.

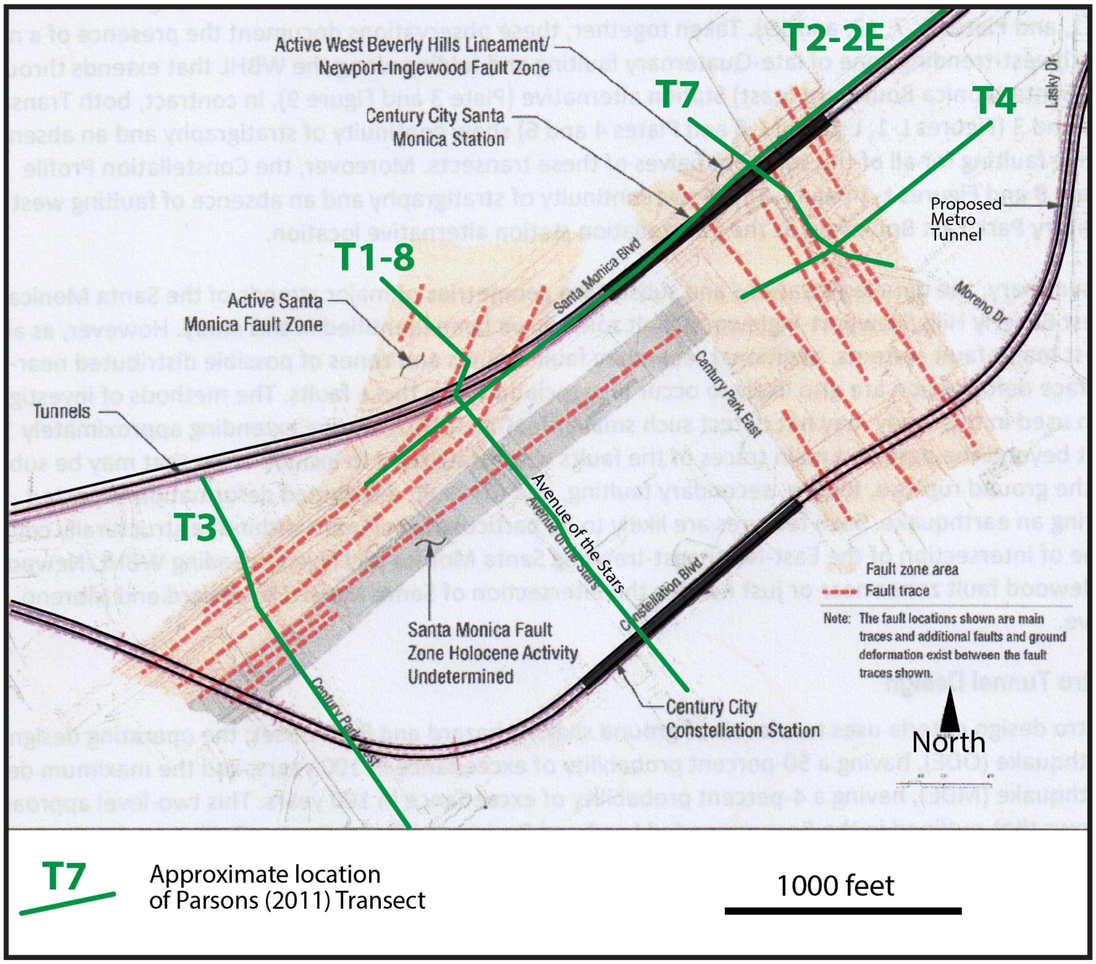
Tsutsumi et al. (2001) based on evaluation of deep well data suggests that the Newport-Inglewood Fault Zone extends north of Bellona Gap and along the southern portion of the West Beverly Hills Lineament (Figures 2, 3 and 4). This interpreted fault was identified in the easternmost oil well in the Cheviot Hills Oil Field (Figure 5) at an approximate depth of 2.2 kilometers (Tsutsumi et al., 2001). Above this depth they show the fault dip at a relatively low angle toward the east, which projects it to the surface near the West Beverly Hills Lineament of Dolan and Sieh (1992; see Figure 4). They indicate that the fault exhibits normal apparent displacement (separation) and without significant if any stratigraphic thickness changes. However, if this fault is projected toward the surface at a relatively steep dip at the location it was identified in the oil well at approximately 2.2 kilometers depth, it projects to a location very similar to the West Pico Fault No. 4 of Erickson and Spaulding (1975) or Wright (1991) located at the eastern most extent of the Cheviot Hills (Figures 4 and 5). Both of these proposed fault locations for the Newport-Inglewood Fault Zone are east of the mapped West Beverly Hills Lineament. The proposed surface location of the Newport-Inglewood Fault Zone by Tsutsumi et al. (2001) is even further west than the western strand proposed by Erickson and Spaulding (1975; see Figure 5). Note that the eastern extent of the Cheviot Hills Oil Field based on data from Wright (1991) extends across the location of the West Beverly Hills Lineament, and the California Division of Oil and Gas (Third Edition 1991) structure map of the Cheviot Hills Oil Field shows no north-northwest striking faults that could be considered a strand of the Newport-Inglewood Fault Zone.

Parsons, (2011) proposed that faults associated with the Newport-Inglewood Fault Zone extends along the West Beverly Hills Lineament as shown in Figure 6 which is discussed in the next section. The findings in this report agrees that similar interpreted faults may occur in the study area associated with the Newport-Inglewood Fault Zone, but that they strike more to the northwest and the western edge of the fault zone is further east. These variations in interpretation are show by comparing Parsons (2011) proposed "Active West Beverly Hills Lineament/Newport-Inglewood Fault Zone (Figure 6) with Fault Zone H proposed by KGS (2013) on Figure 17.

Collectively, these data suggest that deformation associated with Newport-Inglewood Fault Zone, hence, the fault zone itself, extends north of Bellona Gap and along the eastern side of the southern Cheviot Hills including the West Pico Fault No. 4 of Erickson and Spaulding (1975), and the fault shown by Wright (1991) as shown on Figure 5.

Wright (1991) proposes that the Newport-Inglewood fault zone has migrated northward during the late Quaternary. Hence, it is possible that fault strands associated with the Newport-Inglewood Fault Zone north of Bellona Gap developed primarily in the Late middle to late Pleistocene. Freeman et al. (1992) determined a long-term slip rate of 0.31 mm/year on the northern Newport-Inglewood Fault Zone in the region of the Baldwin Hills (Figure 2).

Figure 6: Fault and Transect Location map of Parsons (2011; Figure 9); low resolution per original report.



2.3 West Beverly Hills Lineament

The West Beverly Hills Lineament represents a north-northwest trending east facing slope located on the western edge of the City of Beverly Hills (Dolan and Sieh, 1992; see Figures 2 and 3). There is by no means a unanimous opinion regarding what geologic process produced the West Beverly Hills Lineament. However, recently, the California Geological Survey (CGS) and agreed upon by the United States Geological Survey (Figure 3) has posted a fault map (their website) showing a single fault in the area of the West Beverly Hills Lineament (http://earthquakes.usgs.gov/regional/qfaults/). The placement of the West Beverly Hills Lineament on the official maps did not follow the normal CGS procedure that includes the publishing of a very detailed Fault Evaluation Report: there has been no published Fault Evaluation Report of the West Beverly Hills Lineament by the CGS. It should also be noted that until the present time, there has not been a single fault study or presentation of other hard evidence of the actual presence of a fault zone existing along the West Beverly Hills Lineament. Regardless, the West Beverly Hills Lineament was listed on the CGS maps since 2010 as an active fault. Some published explanations for creation of the topographic West Beverly Hills Lineament include:

- Although published prior to proposal of the term WBHL, Hoots (1931), indicates that Pleistocene age folding (deformation) had occurred in the Cheviot Hills suggesting that uplift and erosion may have played a role in the development of the WBHL.

- Uplift associated with a potential northerly extension of the Newport-Inglewood Fault Zone (NIFZ; see Wright, 1991). This model therefore indicates that uplift, folding, and erosion presumable associated with strike-slip faulting related transpression is the dominant process producing the West Beverly Hills Lineament.

- Faults associated with the northern extension of the right-lateral northwest trending NIFZ. This model suggests that faults associated with the NIFZ extend to the surface or very close to the surface along the West Beverly Hills Lineament. Tsutsumi et al. (2001) provides subsurface structure cross sections based on evaluation of oil well data to extend the NIFZ to the southern Cheviot Hills. Dolan and Sieh (1992) proposed that the NIFZ extends along the WBHL likely all the way to the Hollywood Fault Zone at the base of the Santa Monica Mountains primarily based on geomorphic evidence. Hauksson (1987, 1990) extends the NIFZ northward in the vicinity of the West Beverly Hills Lineament based on evaluation of historical seismicity. Poland et al. (1959) provides boring stratigraphic and groundwater data from borings and wells indicating that the NIFZ extends into Bellona Gap located between the northern Baldwin Hills and the southern Cheviot Hills but notes that it does not offset latest Pleistocene gravels.

- The surface manifestation of a northern extension of the gently east-dipping Compton blind thrust fault (Dolan et al., 1997 extrapolating findings of Shaw and Suppe, 1996).

- An east dipping normal fault associated with extension along the left step between the Hollywood and Santa Monica Fault Zones (Dolan et al., 1997). Presumably this model suggests that a shallow northwest trending normal fault zone produced the West Beverly Hills Lineament escarpment. Interestingly, Tsutsumi et al. (2001) shows a strand of the NIFZ in the southern Cheviot Hills that dips eastward and exhibits a normal apparent offset (their Cross Section G-G'). This interpretation only works if the Santa Monica Fault is much farther south than Santa Monica Boulevard because the normal fault must connect the Santa Monica Fault and Hollywood Fault at their respective terminations. If the WBHL normal falt extends south to the southern par of the Cheviot Hills, then the SMF must be down there as well.

- Lang and Dreessen (1975) propose that the Newport-Inglewood Fault Zone turns westward south of the Cheviot Hills and cuts the Santa Monica fault Zone west of Century City. This model therefore indicates that faults associated with the Newport-Inglewood Fault Zone do not extend northward in the vicinity of the West Beverly Hills Lineament; hence suggesting the lineament has not resulted from the NIFZ. It should be pointed out that Lang and Dreessen evaluated structure at depths greater than 3000 feet associated with the top of the Miocene Topanga Formation.

- An examination of structure contours of early Quaternary gravel members provided by Hummon et al., (1994) indicates a broad northwest-plunging anticline in the Baldwin Hills that extends northward into the southern Cheviot Hills and generally parallel to the WBHL. However, Hummon et al. (1994) does not propose a model for the development of the WBHL.

- Lang (1994) disagrees with the Hummon et al. (1994) findings and indicates that the Wilshire fault does not intersect their mapped trace of the West Beverly Hills Lineament-Newport-Inglewood Fault Zone. Lang (1994) indicates that subsurface mapping, constrained by dense subsurface control from nearly 300 wells in the Cheviot Hills precludes the existence of any fault with the trace that Hummon et al. (1994) showed for the West Beverly Hills Lineament-Newport-Inglewood Fault Zone.

- Based on boring data located approximately one mile southeast of Beverly Hills High School in the Baldwin Hills, Tsutsumi et al. (2001) suggested that the West Beverly Hills Lineament is underlain by an east dipping normal-separation fault that could be a northern continuation of the Inglewood fault. They also indicate that they were unable to locate the subsurface continuation of the lineament or "fault" farther north because of the structural complexity north of the southern strand of the Santa Monica Fault and that right slip across the Inglewood fault is absorbed by growth of the Cheviot Hills anticline and Sawtelle syncline as originally proposed by Wright (1991).

- Dolan et al. (1997) suggest numerous tectonic models for the creation of the West Beverly Hills Lineament. These include an east dipping normal fault associated with extension along the left step between the Hollywood and Santa Monica Fault Zones, a fold scarp along the northern extension of the back limb of the Compton blind thrust anticline and right-lateral strike-slip faulting associated with the northern Newport-Inglewood Fault Zone.

Based on all these different models it is clear that the processes involved in producing the West Beverly Hills Lineament remains poorly understood. The northwest trend of the West Beverly Hills Lineament essentially parallels the trend of the Peninsular Ranges to the south including the Newport-Inglewood Fault Zone, making it very tempting to simply extend the NIFZ northward along the WBHL. The boundary between the Western Transverse Ranges and the Peninsular Ranges is commonly defined as the region of the Santa Monica-Hollywood Fault Zones locally; however even this is complex because the Santa Monica Fault North proposed by Wright (1991) crosses over the West Beverly Hills Lineament. Hence, the boundary between the Western Transverse Ranges and the Peninsular Ranges should be considered a fairly wide zone encompassing the Santa Monica Fault North and South of Wright (1991) and the Hollywood Fault Zone.

The Santa Monica Fault Zone includes numerous strands that once projected to the surface occur along and south of Santa Monica Boulevard (Figure 5). Hence, the boundary of the Western Transverse Ranges and Peninsular Ranges occurs within the central and southern Cheviot Hills but steps northward east of the West Beverly Hills Lineament to join with the Hollywood Fault Zone. However, the Santa Monica Boulevard Fault Zone (Figure 5; Fault Zone F in Figure 17) in Century City may continue across the West Beverly Hills Lineament to a fault zone defining the southern Hollywood Basin (i.e. Santa Monica Fault North of Wright [1991] and North Salt Lake Fault). In any case, the West Beverly Hills Lineament extends north of the central Cheviot Hills along Santa Monica Boulevard to the base of the Santa Monica Mountains (Figure 3). Hence, the lineament extends across the commonly published boundary between the Western Transverse Ranges and Peninsular Ranges. Erickson and Spaulding (1975) and Wright (1991) identified strands of the Newport-Inglewood Fault Zone in the southeastern and east of the Cheviot Hills (Figures 4 and 5). Western strands of these faults may connect with Fault Zone H of this study (Figures 13 and 17). These data suggest that strands of the Newport-Inglewood Fault

Zone encounter the Santa Monica Boulevard Fault as shown in Figure 4. Fault Zone F within the Santa Monica Boulevard Fault Zone is not active (LCI, 2012a; Geocon, 2013a) and the Newport-Inglewood Fault is considered active (Byrant and Hart, 2007). This suggests that Fault Zone H may offset Fault Zone F in Century City. There is no evidence however to suggest that Fault Zone H offsets Fault Zone A (Figure 17).

2.4 Regional and local fault systems for this study

The general location and names of regional fault zone systems in the region of the site are shown in Figure 4. The name Santa Monica Fault is maintained for the section of fault similar to the Potrero Canyon Fault of Wright (1991) near the VA Hospital and to the west (Figure 4, red dashed line). In this area, a low angle, north-dipping fault associated with the Santa Monica Fault Zone may occur that projects to the surface near Ohio Street south of the VA Hospital (Catchings, et al., 2008; Catchings et al., 2010). This fault system is proposed to continue nearly due east under the southern Cheviot Hills as a blind reverse fault (Figure 4, orange dashed line).

Fault evaluation studies conducted by MACTEC (2010) and Parsons (2011) have interpreted several faults in the vicinity of Santa Monica Boulevard that support that the topographic lineament along Santa Monica Boulevard resulted from faulting and subsequent erosion along the fault zone. Parsons (2011) interpreted numerous northeast trending faults along Santa Monica Boulevard they referred to as the Santa Monica Fault Zone (SMFZ) and northwest trending faults associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zones (WBHL-NIFZ; Figure 5). However, as indicated earlier, northeast trending faults along Santa Monica Boulevard are referred to as the Santa Monica Blvd Fault Zone (SMBFZ).

Parsons (2011) - without any sediment age data to evaluate the age of faulting - presumed that their interpreted faults along Santa Monica Boulevard and the West Beverly Hills Lineament – Newport Inglewood Fault Zone are active due to their correlation of these fault zones with identified active faults in the region. Parsons (2011) presumed that the Santa Monica Fault Zone is active based on a paleoseismic study conducted at the Veterans Administration West Los Angeles Hospital site by Dolan et al. (2000a). Additionally, Parsons (2011) presumed that faults they identified within the West Beverly Hills Lineament – Newport Inglewood Fault Zone were active based on their correlation of this zone with the active Newport-Inglewood Fault Zone (Byrant and Hart, 2007) located approximate 2.5 miles to the south (Figure 2).

3.0 EVALUATION OF SUBSURFACE DATA

Subsurface data utilized in this study are from numerous studies (Figure 1), which are listed and briefly discussed below.

- Parsons Brinckerhoff (Parsons, 2011) fault investigation in Century City. Subsurface data from this report involved abundant continuous borings, Cone Penetration Tests (CPT) and seismic reflection/refraction data along several Transects (T1-8, T2-2E, T3, T4 and T7). The Parsons (2011) report also included subsurface boring and seismic data from MACTEC (2010). The Parsons (2011) report included geotechnical boring data along Constellation Boulevard conducted by others and over the course of many decades.
- Leighton Consulting, Inc. (LCI, 2012a) fault investigation at Beverly Hills High School. This report provided numerous continuous borings in the Beverly High School area and a number of

fault trenches. This study focused primarily along three cross sections named A-A', B-B' and C-C' as shown on Plate KGS-FM1. Cross Sections A-A' and C-C' occur along portions of Transects T4 and T5 of this study.

- Leighton Consulting, Inc. (LCI, 2012b) subsurface fault evaluation of the El Rodeo K-12 School. This report consisted of a series of continuous borings along their cross sections A-A' and B-B'.
- Feffer-Geocon (2012) fault investigation at 10,000 Santa Monica Boulevard. Subsurface data consisted of an approximately 300-foot long, 25-foot deep fault trench near the intersections of Transects T2, T5 and T7 (this study).
- Geocon (2013a) fault rupture hazard evaluation at 9900 Wilshire Boulevard. This report contains geotechnical borings (non-continuous) that were originally conducted by MACTEC (2008). These data were utilized along a portion of Transect 7.
- Geocon (2013b) fault rupture hazard evaluation at the Westfield Century City Mall. Most of the data utilized for this study was conducted along the Avenue of the Stars for Geocon's cross section A-A' and along Transect 1 (this study). However, additional data was collected by Geocon (2013b) along Century Park West for their cross section B-B' that was not evaluated in detail for this study due to time constraints and a lack of Holocene age sediments in this area.
- TRC (2008) additional site assessment report for the California Regional Water Quality Control Board for 9988 Wilshire Boulevard. Subsurface data from this report includes boring logs for water monitoring borings in addition to groundwater levels measured over a number of years. These data were utilized along a portion of Transect 7.
- MACTEC (2010) seismic exploration for the Santa Monica Fault along the Metro West Side Extension. Subsurface data utilized from this report includes a few sonic core borings and two seismic lines located near the Mormon Temple and Avenue of the Stars.
- Legg Geophysical, Inc. (Legg, 2012a and 2012b) independent review of Parsons (2011) seismic data. These reports provide a second opinion evaluation of the Parsons (2011) seismic reflection survey data by Dr. Mark Legg along Transects T1, T3, T4 and T7.

The majority of the stratigraphic and structural findings provided in this report resulted from the re-interpretation of the boring and CPT data provided in the above referenced reports (Section 5.0). The findings provided by seismic geophysical reflection studies by Parsons (2011), MACTEC (2010) and Legg (2012a and 2012b) were not re-interpreted by the author during this study. However, Legg (2012a and 2012b) does provide a secondary evaluation of the Parsons (2011) data, which was utilized in this study.

3.1 Fault trench data

Fault investigation trench data was evaluated from the LCI (2012a) investigation at Beverly Hills High School, and from Feffer-Geocon (2012) at 10,000 Santa Monica Boulevard (Figure 1). These reports provided important data on the local stratigraphy exposed in the trenches and numerical soil ages.

3.2 Boring data

Boring data was utilized from the LCI (2012a and 2012b), Geocon (2013a and 2013b), and TRC (2008) investigation (Figure 1). The boring locations identified within each respective report were utilized with the exception of several boings in the region of Cross Section A-A' of Geocon (2013b) that discovered based on an independent survey of roadway markings were not properly located in the Parson (2011) maps and transects. These borings occur south of Santa Monica Boulevard on Transect 1 (Plate KGS-

T1). This report utilizes the revised locations by Geocon (2013b) on their cross-section A-A' as shown on Plate KGS-T1.

Continuous core borings were evaluated for the Geocon (2013b), LCI (2012a and 2012b), and Parsons (2011). Continuous core data by Geocon (2013b) along Century Park West along their Cross Section B-B' were not utilized during this study. Continuous cores by Geocon (2013b) and LCI (2012a and 2012b) provided important pedogenic soil horizons and their numerical ages were extremely useful. Many of their positively identified soil horizons were correlated to suspected soils in the Parsons (2011) continuous cores.

Geotechnical or groundwater monitor well boring logs with interval sample depths were utilized from the Geocon (2013a) and TRC (2008) reports for the 9900 and 9988 Wilshire Boulevard properties respectively (Figure 1). The monitored groundwater elevations provided in the TRC (2008) report for the 9988 Wilshire Boulevard property were utilized to evaluate local faulting.

Boring log evaluation involved splicing together each log and identifying with colors numerous characteristics. These include color coding based on their grain size (composition): fat clays (CH) red; clay (CL) orange; silts (ML) not colored; sands (i.e. SM, SP, SW) yellow, and gravels green; identified of potential soil development indicators; identification of potential erosional surfaces (i.e. gravels over finer grained sediments), and fining upward sequences. Some of these identifiable characteristics are discussed in more detail in following sections.

3.3 CPT data

CPT data was provided from Parson (2011) along their transects shown on Figure 5. Similar to the borings locations of Parsons (2011) on Transect 1, Geocon (2013b) discovered that several CPT locations were misplaced. The revised locations of these data are shown on Plate KGS-T1.

3.4 Geophysical seismic reflection data

Seismic reflection data was utilized for this report from Parsons (2011) and MACTEC (2010). The general location of the Parsons (2011) seismic lines is shown on Plate KGS-FM1. The MACTEC (2010) report evaluated seismic reflection analysis in the study area and near the Mormon Temple. For the purposes of this study, Dr. Mark Legg (2012a and 2012b) provided an independent evaluation of the Parsons (2011) seismic lines.

3.5 Oxide and carbonate deposits

Many of the boring logs indicated the presence of oxides (i.e. oxidized zone, Manganese or Iron oxides), which were utilized as a parameter to assist in correlating between borings. The Parsons (2011) boring logs consistently recorded oxide deposits (manganese and iron oxide) and carbonate concentrations and morphology. The accuracy of their records is supported by correlation of sediments between Parsons (2011) and LCI (2012a) boring logs for adjacent borings along Transect T4 (Plate KGS-T4).

Parsons (2011) logs routinely describe carbonate deposits by their morphology and abundance (i.e. trace, abundant, percentage, nodules). The carbonates documented in the Parsons (2011) logs were correctly not assumed to be necessarily of pedogenic origin. Where a well-defined Bt (argillic) horizon was identified or known to exist, then the corresponding carbonate was likely pedogenic in origin and labeled as "Bk". Otherwise, layers containing carbonate were appropriately labeled as "Ca", which may or not be carbonate of pedogenic origin (i.e. possible groundwater migration origin).

3.6 Interpretation of argillic horizon clay “shear surfaces”

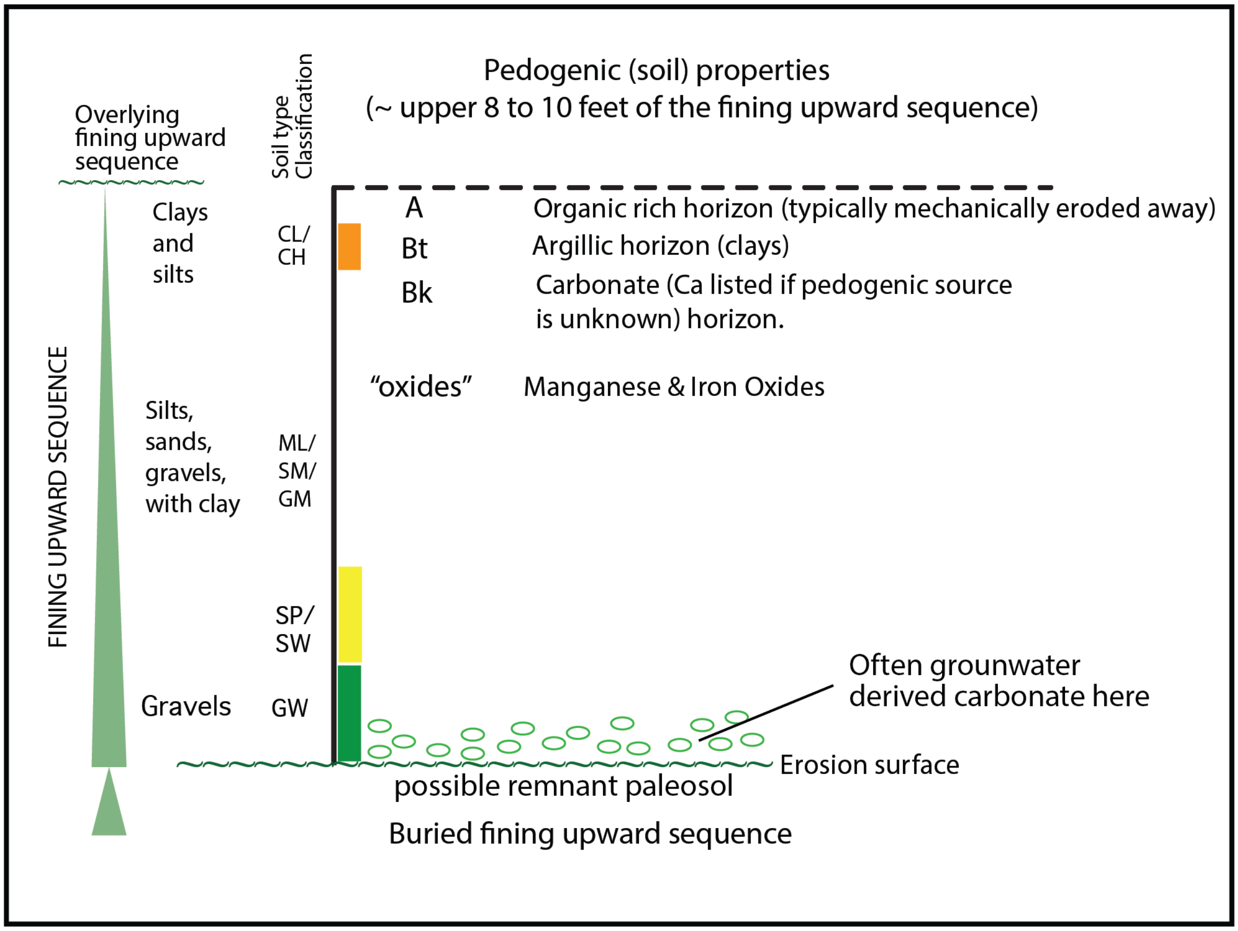
Parsons (2011) identified numerous “shear surfaces” in its boring logs and considered these shear surfaces tectonic in origin. The LCI (2012a) trench exposures and continuous cores provided the opportunity to closely examine these “shear surfaces” and revealed that many of the Parsons (2011) “shear surfaces” are likely not tectonic in origin, but rather relate to expansive “shrink-swell” of clay that comprise the argillic horizons of area-wide paleosols.

3.7 Fining upward sequences

Fining upward sequences primarily develop in terrestrial fluvial systems due to climatically driven variations in stream behavior, which frequently occurred during the “ice age” (Pleistocene). For example, throughout California’s Mediterranean climate and vegetation regimes, epochs of lower base level are associated with regionally pluviality and channel incision during periods of glaciation. With glacial melting, sea levels rise and channels are back-filled, initially with coarse-grained sediments followed by sand and later silt. During epochs of regional landscape stability (interglacial or inter-stadial) pedogenic soil profiles develop. Eventually the process is repeated with onset of the next climatically controlled erosional and depositional cycle (Shlemon, 1972; Bull, 2000). The end product is often several grossly fining upward sequences that are reflections of regional climatic and vegetation change. The presence of fining upward sequences proved useful for the evaluation of unconformities and marker horizons to correlate between borings and across faults. Marine deposits (i.e. Lakewood and San Pedro Formations) exhibited a paucity of fining upward sequences but they are very common in the overlying Cheviot Hills and Benedict Canyon deposits. Fining upward sequences were identified in most of the continuous cored borings primarily from the Parsons (2011), LCI (2012a and 2012b) and Geocon (2013b) reports.

The top of fining upward sequences generally exhibits a soil profile (i.e. A, Bt (argillic clay) and Bk (carbonate) horizons in addition to the increased abundance of oxides (manganese and iron) below the soil horizons (Figure 7). Rarely are the A horizons preserved in pre-Holocene age soils due to chemical weathering (oxidation) or mechanical weathering which includes erosion associated with the overlying fining upward sequence. The depth of secondary material (i.e. clay and oxides) is a function of their solubility. For example, translocated clay is the least soluble and manganese oxide is the most soluble thus allowing the manganese oxide extend to the deepest depths in the soil profile. Multiple “k” horizons (carbonates) often occur and indicate a climatic change. Bt and Bk horizons are commonly persevered, however in many instances these layers may also be eroded, which only leave the oxide layers in the stratigraphic record. The base of the fining upward sequences is marked by an increase in coarse-grained sediments (sands and gravels). The Parsons (2011) boring logs provided estimated percent gravel in specific layers even if the gravel content was as low as a trace or 5 percent. This proved very useful for evaluating the base of many fining upward sequences along the Transects with adequate boing density. The CPT data also assisted in the evaluation of fining upward sequences due to the relative change in response of clays vs. coarse-grained sediments. However, in many instances, the Parsons boring core samples did not correspond well to adjacent Parsons CPT data. For example, a small increase in sand or gravel in a dominantly silt or clay often produced a CPT “spike”, and hence the inference that different units were present. Hence, the boring data was weighted more heavily than the CPT data in many instances.

Figure 7: General Characteristics of a Fining Upward Sequence.

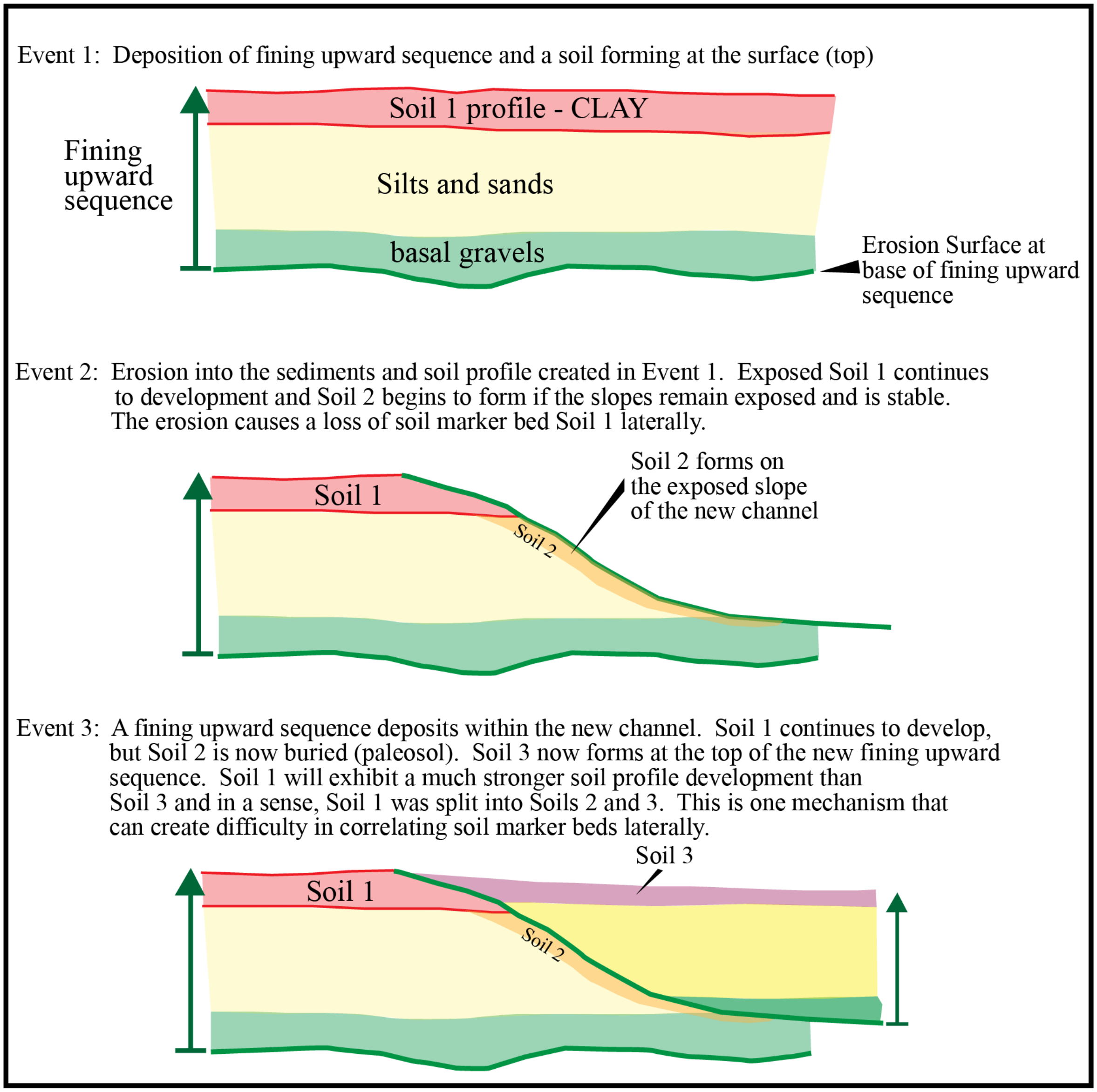


3.8 Evolving soil landscapes

Basal erosion surfaces can provide reasonable marker horizons, however, by their nature underlying units were eroded to variable stratigraphic depths. This process can remove underlying marker beds, which are often pedogenic soil horizons. Additionally, depending on stream power, basal erosion surfaces can dip at fairly steep angles, thus suggesting the presence of faulting where none exist (Figure 8).

Many marker beds in the Parsons (2011) report and this study are soil profiles that formed on a stable geomorphic stable surface; however, landscapes constantly evolve over time. As shown in Figure 8, a soil may form on an original surface (Event 1, Soil 1), and is then partially eroded to create a gully or canyon. Depending on slope, a second soil may form (Soil 2) on the canyon wall or on sediments partially filling in the canyon. At the same time Soil 1 continues to form and becomes more strongly developed (Event 2). When additional sediments fill the gully (a fining upward sequence) and eventually cease deposition, a third soil will form (Soil 3), and this may be at relatively the same elevation as Soil 1 (Event 3). Such relationships may lead to an erroneous interpretation that a fault is present between borings due to the "loss" of a soil marker.

Figure 8: Example of soil development across an evolving landscape.



3.9 Folding

Another potential misinterpretation for fault presence stems from tilted/folded beds (KGS, 2012). Figure 9 reinterprets the Parsons (2011) Constellation Transect, which shows beds folded into an antiform and not assumed to be horizontal. Here, the gravel members in the lower portion of the cross-section transect align almost perfectly if the units are assumed to be tilted only 1.5 degrees. Parsons (2011) assumed these units were horizontal, and hence that faults are present. One of the likely reasons for their interpretation resulted from utilizing a vertical scale that was 10 times that of the horizontal scale. This inherently gives the impression of large vertical discontinuities between the boring and CPT subsurface data. Figure 10 shows the Constellation Boulevard cross-section with no vertical exaggeration.

Figure 9: Transect of Parsons along Constellation Boulevard (A), and reinterpretation Constellation Boulevard Transect (B). Figure modified from KGS (2012).

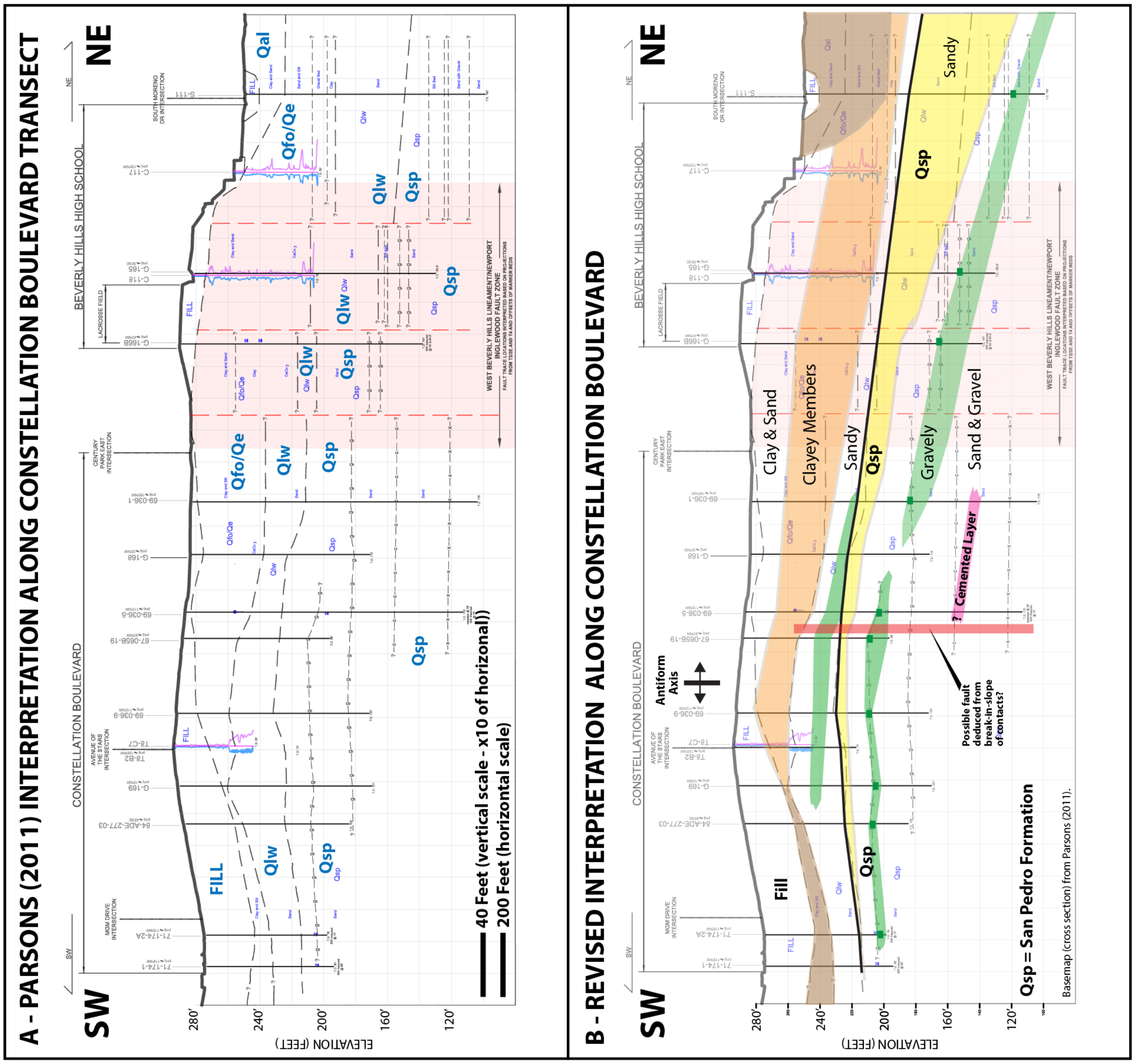
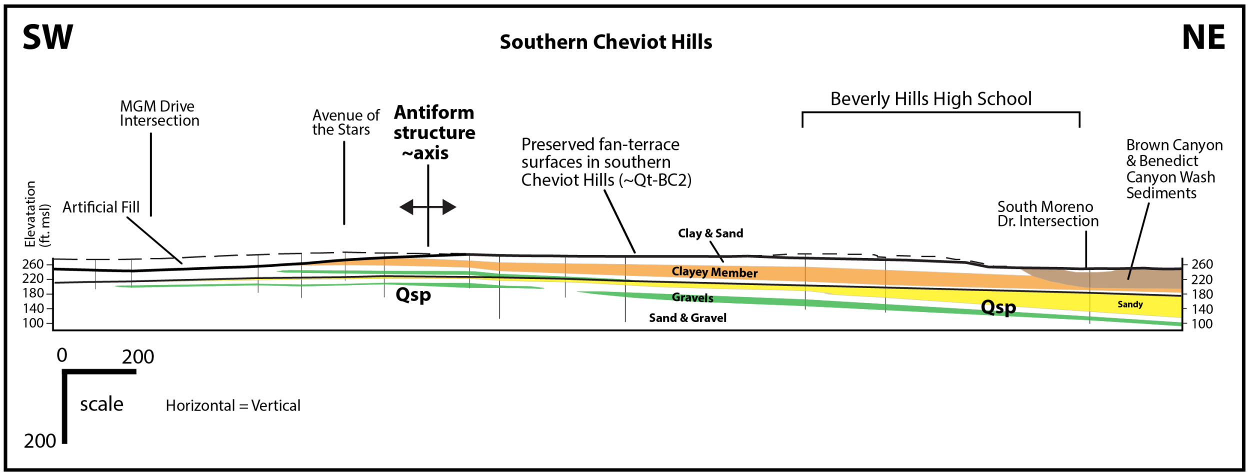


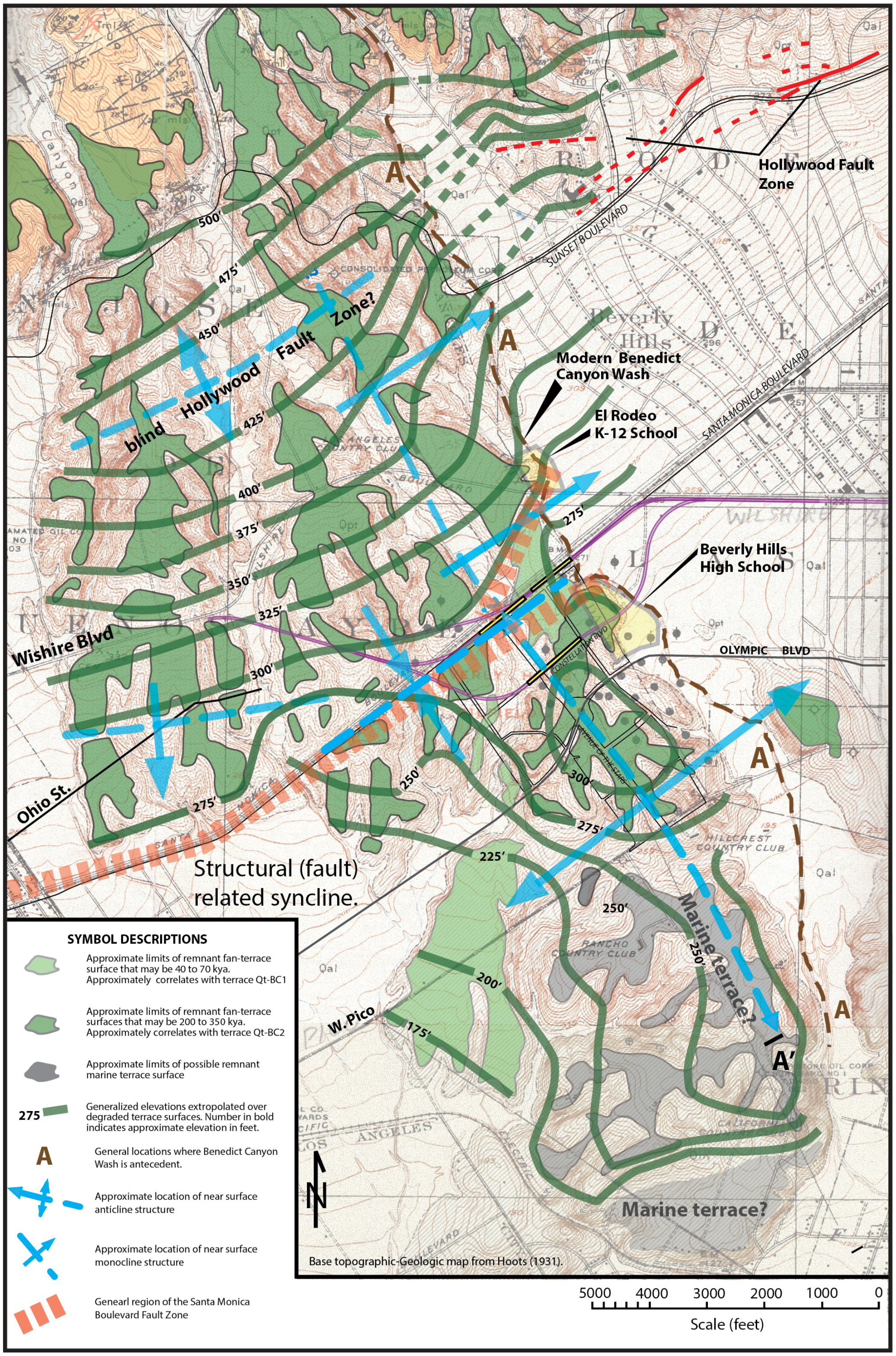
Figure 10: Constellation Boulevard Transect with revised interpretation and with no vertical scale exaggeration (modified from KGS, 2012).



Folding is also observed in the preserved fan surfaces in the southern Cheviot Hills (KGS, 2011, 2012). The gentle (open) fold trends north-northwest parallel to the WBHL (Figure 11) and the limbs of the fold are generally parallel to the contact of the upper limits of the San Pedro Formation (compare Figures 10 and 11) suggesting that uplift and folding may have begun since the time of upper San Pedro Formation locally. Evaluation of the transect cross-sections shows a thinning of units in the upper San Pedro Sequence and younger units along the axis of the fold suggesting that these units may have been deposited during uplift (folding).

Additional fold structures in the area may include a broad east-west trending warp in the northern Cheviot Hills as identified by relatively widely spaced contours identified in the preserved fan-terraces. The axis of this possible fold aligns with the Hollywood Fault Zone to the east across the WBHL and suggests surface deformation associated with this fault zone if blind. A structural likely fault induced synclinal fold structure occurs along Santa Monica Boulevard in the central Cheviot Hills (Figure 11). Units to the north of Santa Monica Boulevard generally dip toward the south and units to south generally dip toward the north (see Plates KGS-T1 and KGS-T3). The preserved fan-terrace surfaces also exhibit a change in dip across this zone (slope inflection point; Figure 11). In addition, fan-terrace surfaces in Figure 11 show typical fan morphology north of Santa Monica Boulevard, and a fold south of Santa Monica Boulevard suggesting that magnitude and styles of deformation are different in the northern and southern Cheviot Hills. Note that the identified WBHL of Dolan and Sieh (1992) are continuous along the entire eastern side of the Cheviot Hills.

Figure 11: Geomorphic map of the Cheviot Hills region. Figure modified from KGS (2011 and 2012).



4.0 QUARTERNARY STRATIGRAPHIC FRAMEWORK

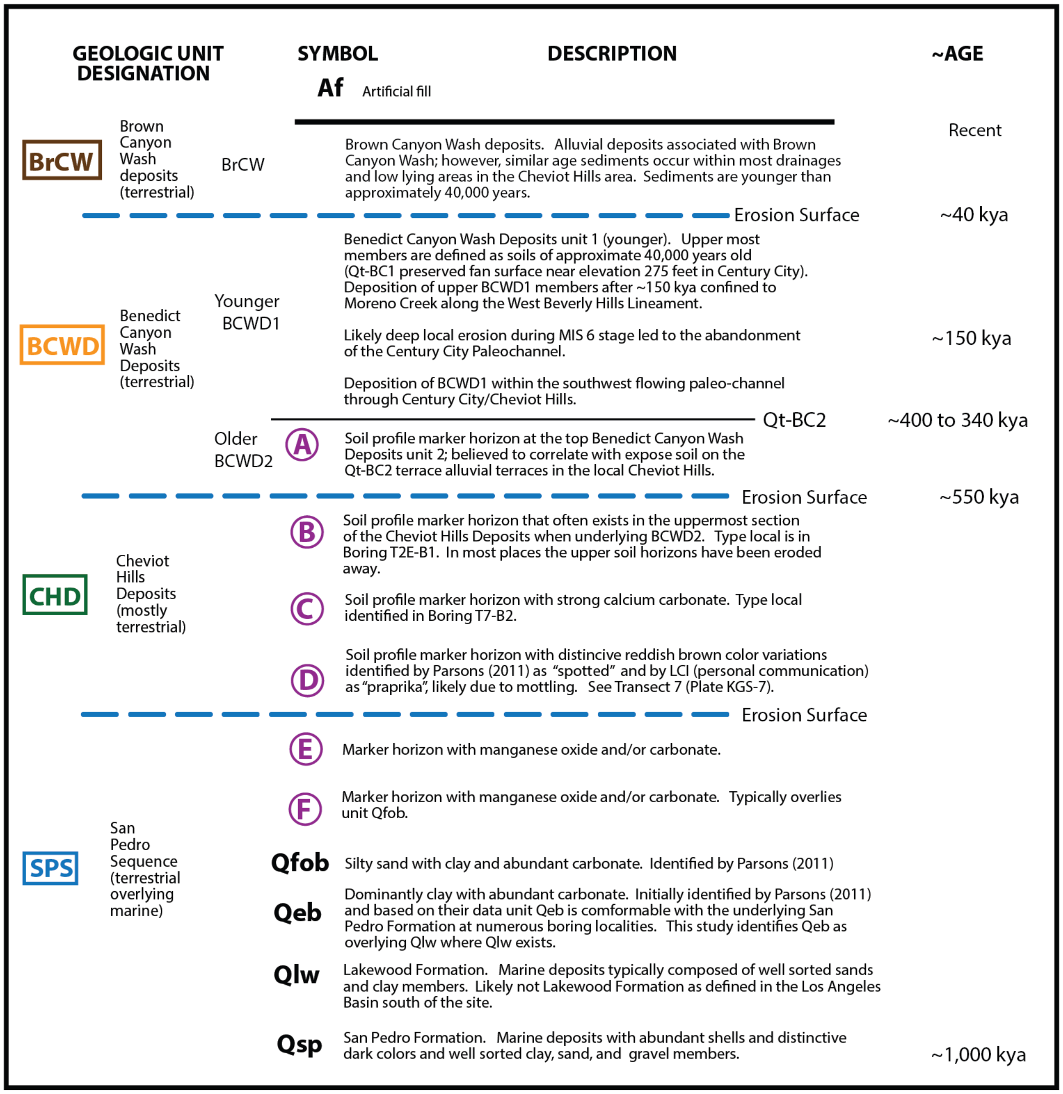
The upper approximately 200 feet of geologic sediments have been designated into four depositional units based on age, depositional environment, and structure (deformational history). They include from youngest to oldest: the Brown Canyon Wash deposits (BrCW); the Benedict Canyon Wash Deposits (BCWD); the Cheviot Hills Deposits (CHD); and the San Pedro Sequence (SPS). The BCWD are subdivided into two units, BCWD1 (younger) and BCWD2 (Figure 7). Numerous marker beds were also identified within these designated units that were correlated laterally throughout the study area. These include marker beds A through F, Qfob and Qeb (Figure 7). Locally, marker beds identified by other studies were also utilized on some transects (cross-sections).

The Brown Canyon Wash deposits are latest Pleistocene through late Holocene terrestrial alluvial sediments with the type section within Brown Canyon Wash in Century City (Figure 9). However, BrCW deposits also occur within drainages throughout the study area including sediments associated with Moreno Creek that emanates from Benedict Canyon in the Santa Monica Mountains. The Benedict Canyon Wash Deposits (BCWD) represents late Pleistocene terrestrial deposits composed of alluvial sediments primarily derived from the local Santa Monica Mountains. Marker horizon A delineates the approximate upper member of the BCWD1, hence the approximate contact between units BCWD1 and BCWD2. The CHD represents terrestrial alluvial sediments deposited after the SPS and prior to the BCWD with both the upper and lower contacts exhibiting relatively well-developed erosion surfaces (unconformities). The SPS includes the marine San Pedro and Lakewood Formations, which are the oldest units evaluated in this study and some overlying sediments associated with marker beds E, F, Qfob and Qeb, which are mostly terrestrial (Figure 7). This section provides a general overview of the definition of the designated geologic units. Section 4 discusses how specific ages were assigned to these units.

4.1 Brown Canyon Wash Deposits (BrCW)

Brown Canyon Wash deposits (BrCW) consists of terrestrial alluvium composed of sediments shed from the Santa Monica Mountains and local erosion of older exposed sediments within the Cheviot Hills. The BrCW deposits occur within inset drainages throughout the Cheviot Hills and across the gently sloping fan surface immediately east of the West Beverly Hills Lineament, which locally involves the Moreno Creek (Benedict Canyon; Figure 9). The type section of the BrCW deposits is defined based on an evaluation of soil descriptions and numerical soil ages provided by Geocon (2013b; see Helms, 2013), which was within Brown Canyon Wash (Brown Canyon Wash on Figures 8 & 10). In addition, numerical ages and approximate depth limits for this unit were also provided associated with Moreno Creek (Benedict Canyon) in Beverly Hills High School by ECI (2012; Fault Trench 2). This unit is generally 10 to 15 feet thick locally.

Figure 12: Stratigraphic section for the Cheviot Hills in the Century City area.



4.2 Benedict Canyon Wash Deposits (BCWD1 and BCWD2)

Benedict Canyon Wash Deposits (BCWD) consists of terrestrial "older alluvium" composed of sediments shed from the Santa Monica Mountains to the north via primarily from washes emanating from Benedict Canyon Brown, Stope and Dry Canyons (Figure 7). A large quantity of sediments transported from the Santa Monica Mountains emanate from the relatively largest drainage, Benedict Canyon, that now flows along Moreno Creek on the eastern side of the WBHL (Figure 7). However, washes within Brown, Stope and Dry Canyons also provided sediments to the Cheviot Hills region during the late Pleistocene (Figure 7).

The BCWD is divided into younger (BCWD1) and older (BCWD2) as shown on the stratigraphic section of Figure 7. BCWD2 is exposed on preserved fan terraces throughout the central and northern Cheviot Hills (Figure 10). Hence, it represents that last sediments deposited on the local preserved fan surfaces (Qt-BC2) in the central and northern Cheviot Hills. BCWD2 was deposited primarily from Brown and Benedict Canyons (Figure 13) as an alluvial fan-bajada throughout the Cheviot Hills area prior to development of the topographic relief (uplift) associated with the Cheviot Hills. However the "BCWD2" fan itself may have exhibited some local relief simply due to depositional processes and not tectonic forces. By definition, BCWD2 ceased deposition once the preserved alluvial fan surface (terrace) Qt-BC2 was abandoned (Figure 14) and generally correlates with the inception of the paleo-channel through Century City (Figure 19) from which BCWD1 was confined.

This unit grossly fines upwards from dominantly sands and gravels above the prominent erosion surface at its base to dominantly silts and clays upper members associated with prominent soil marker horizon A (Figure 12). Soil Marker A occurs at the top of a relatively thick fining upward sequence suggesting that BCWD2 may have exhibited a relatively fast depositional rate compared to the relatively clay rich upper member members of underlying CHD. BCWD2 is evaluated to exist as the capping unit on the locally preserved fan-terraces of Qt-BC2. This correlation is based on several lines of evidence. In Beverly Hills High School, the distinctive stratigraphy of fining upward sequence of Soil Marker A and the underlying coarse grained basal members in LCI (2012a) fault trench FT-5 projects to the toward the Qt-BC2 surface exposed in their fault trench FT-1 where similar stratigraphy is exposed (Plate KGS T5). The gravel layer identified by LCI (2012a) in their fault trench FT-1 is more coarse-grained than typical Cheviot Hills Deposits (CHD), which also suggests that this unit is BCWD2. Second, the capping unit at the El Rodeo school on the Qt-BC2 surface is also dominantly coarse grained suggesting it is not CHD. Hence, it is proposed that BCWD2 were deposited during faulting along Fault Zones A and F allowing for the unit to be thicker in the down-dropped region between these faults. However, it is estimated that during MIS 10 to 11, the Qt-BC2 surfaces were abandoned allowing for the soil on those surfaces to continue to develop to modern times. At the same time, Soil Marker A was buried in the down-dropped region between Fault Zones A and F by BCWD1 as faulting along these zones continued and flow within the paleo-channel occurred. The time of abandonment of the Qt-BC2 fan terrace approximately correlates with the time when uplift vs. depositional rates in the Cheviot Hills area were sufficient to allow for the development of abandoned terraces that remain today. Hence, this is likely the period of time of WBHL development and possibly initiation or an increase in rate of folding and associated uplift in the southern Cheviot Hills

In summary, cessation of deposition of BCWD2 and beginning of soil development of Soil Marker A and the Qt-BC2 surfaces may have been associated with the end of a glacial maximum, which is estimated to be around MIS 11 to 10 at approximately 400,000 to 350,000 years ago (Figure 19). Soil marker A also defines the approximate contact between BCWD1 and BCWD2 within the areas where BCWD1 was deposited. Please see Section 5.3 of this report for additional age data for BCWD2.

BCWD1 is confined to drainages within the Cheviot Hills below the Qt-BC2 surfaces and is the dominant unit deposited within the paleo-channel flowing through Century City. The south-southwest flowing paleo-channel through Century City and the central Cheviot Hills may have developed as a result of faulting within the Santa Monica Boulevard fault zone, which produced a "graben" (down-dropped) type region between Fault Zones A and F (Figure 16). Incision associated with the low sea level stand of MIS 6 approximately 150,000 years ago is estimated to correlate with abandonment of the paleo-channel through Century City (Figures 15 and 19). At this time, preserved fan-terrace surface Qt-BC1 developed and deposition on the fan lobe in the southwestern Cheviot Hills was abandoned. Likely minor amounts of BCWD1 was deposited in Brown Wash after the abandonment of the Qt-BC1 surface with most deposition occurring along the modern Moreno Creek area east of the WBHL.

Figure 13: Shaded relief map of the local Santa Monica Mountains and Cheviot Hills area showing primary drainages providing sediments for local alluvial sediments (BCWD and CHD), approximate published mapped locations and postulated faults.

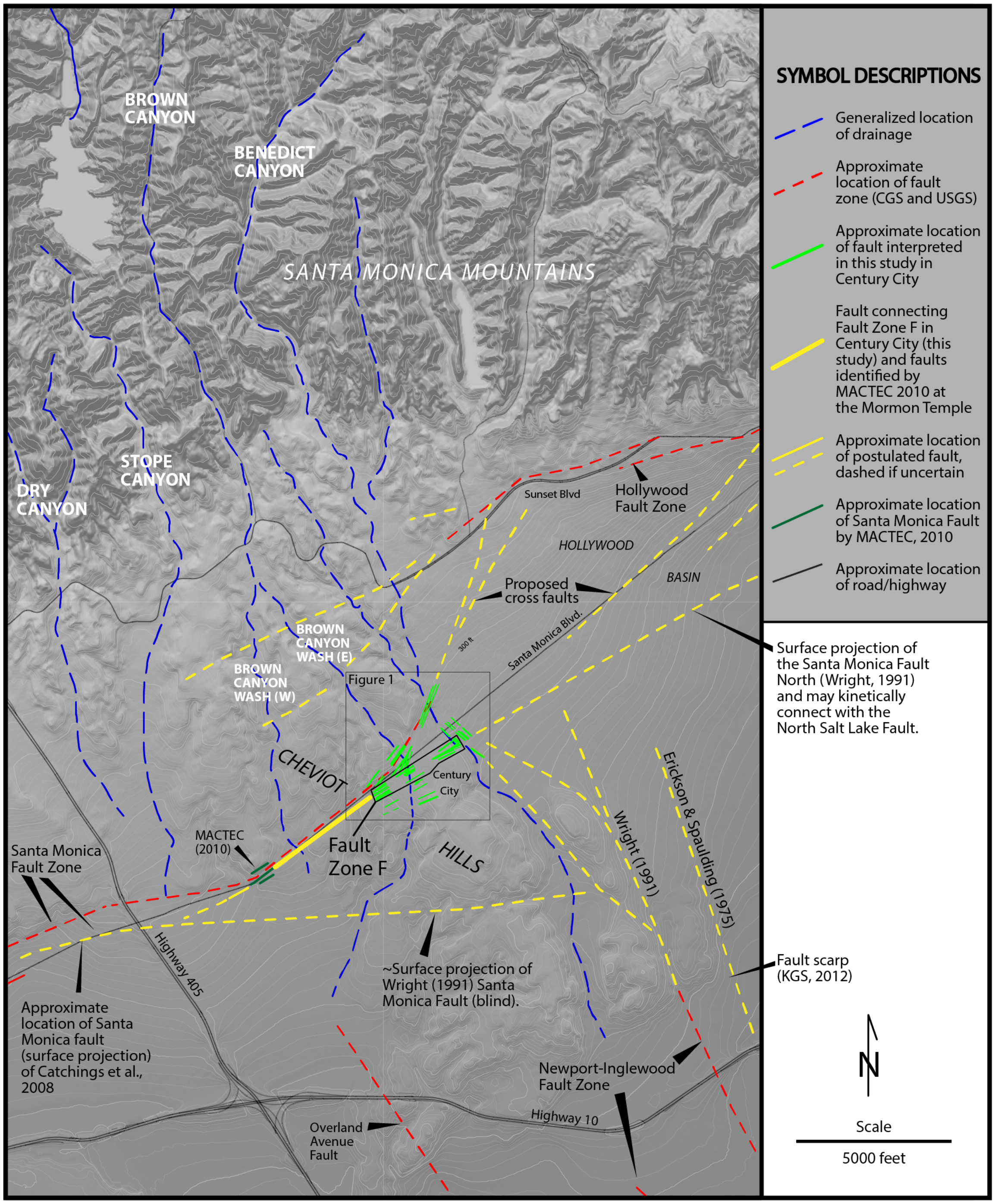
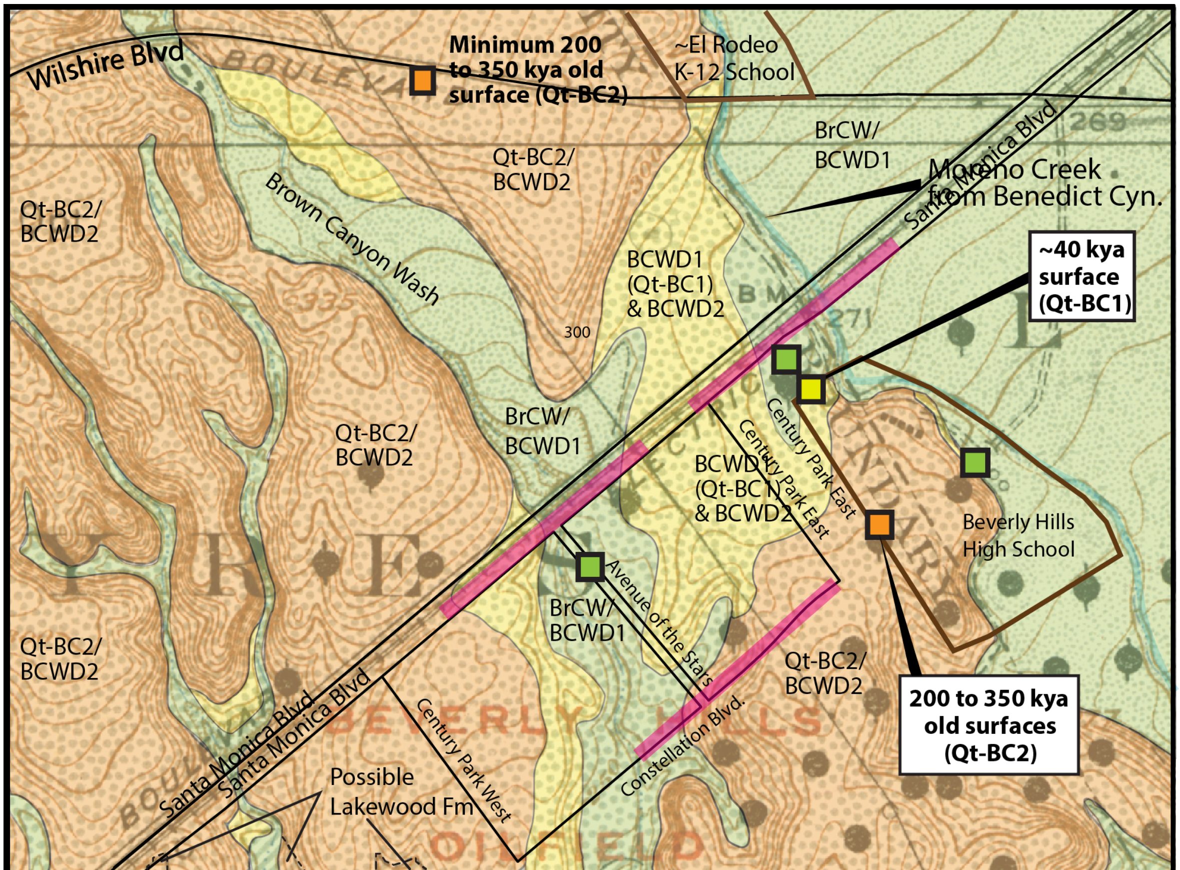


Figure 14: Generalized geologic map of the Century City area



Base topographic-Geologic map from Hoots (1931).

SYMBOL DESCRIPTIONS

BrCW/ BCWD1	Generalized limits of latest Pleistocene to Holocene Brown Canyon Wash deposits overlying younger Benedict Canyon Wash Deposits (BCWD1). Older Benedict Canyon Wash Deposits may also be at depth (BCWD2).
BCWD1 (Qt-BC1)/ BCWD2	Generalized limits of Benedict Canyon Wash Deposits younger member (BCWD1) overlying older member (BCWD2). Ancient drainage system during BCWD1 deposition. General region of preserved Qt-BC1 alluvial surface.
BCWD2 (Qt-BC2)/ CHD	Generalized limits of Benedict Canyon Wash Deposits older member (BCWD2) overlying Cheviot Hills Deposits (CHD). General region of preserved Qt-BC2 alluvial surface. CHD may be exposed on the flanks of some of the relatively deeply incised drainages.
Yellow square	Approximate location of ~40 kya soil age provided for the Qt-BC1 surface (top of BCWD1).
Green square	Approximate location of ~40 kya soil age provided for top of BCWD1 where burried by BrCW.
Orange square	Approximate location of correlated soils on Qt-BC2 preserved alluvial fan surface.
Pink bar	Approximate location of Proposed Metro Stations along Santa Monica Boulevard and Constellation Boulevard.

scale (feet)
1000

N

Figure 15: The general location of the Benedict Canyon Wash (BCWD1) paleo-channel and generalized geologic of the Cheviot Hills.

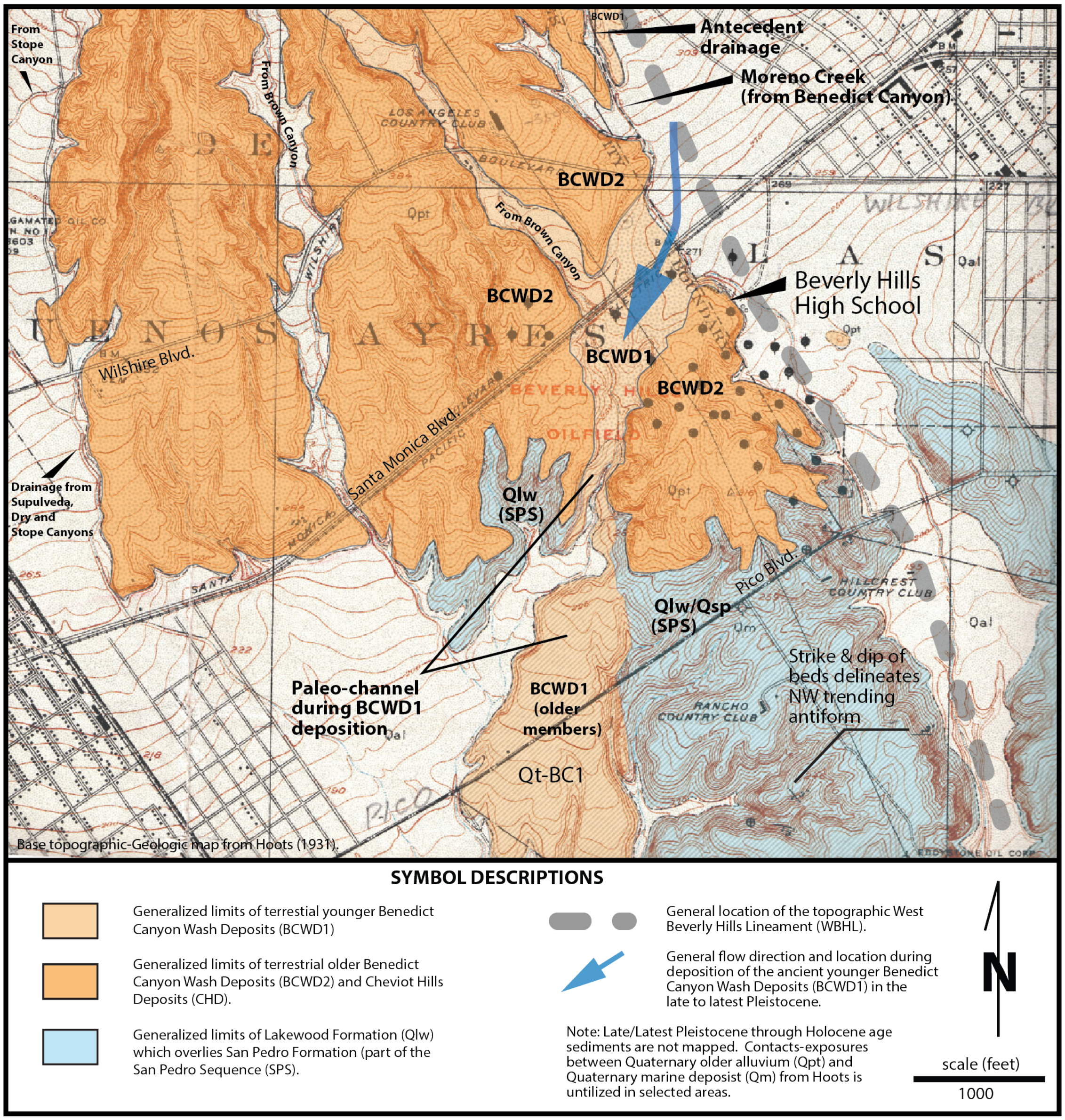
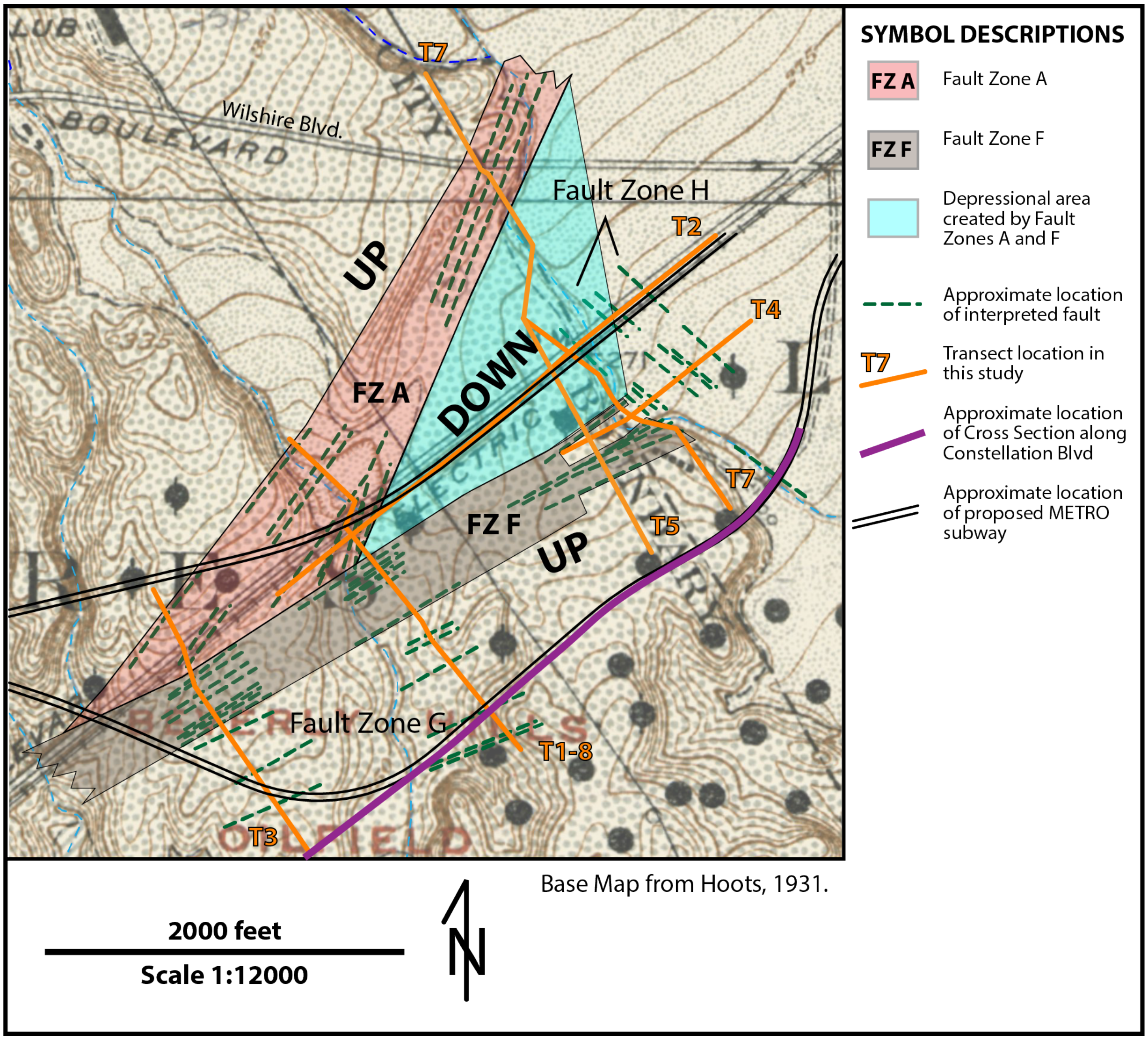


Figure 16: Map of the depressional area between Fault Zones A and F that assisted in the development of the southerly flowing paleo-channel associated with deposition of the Benedict Canyon Wash Deposits (BCWD1 – older member)



4.3 Cheviot Hills Deposits (CHD)

The Cheviot Hills Deposits (CHD) is defined as terrestrial alluvial sediments older than the older Benedict Canyon Wash Deposits (BCWD2) and younger than the San Pedro Sequence. The upper members of the CHD exhibits more fine grained sediments (silts and clays) than the overlying BCWD2, which in addition to the prominent erosion surface at the base of the BCWD2 assists in its identification. The relative abundance of clay in the upper members of the CHD suggests that it was likely deposited in a more distal portion of the fan system than BCWD2. However, the basal members of the CHD exhibits abundant coarse-grained sediments associated with a basal erosion surface that eroded to various stratigraphic levels within the underlying San Pedro Sequence (SPS). Marker Bed B (Figure 7) stratigraphically located in the upper third of the Cheviot Hills Deposits and is estimated to be a minimum of approximately 500,000 to 650,000 years old based on correlation with numerically dated sediments in the Beverly Hills High School (LCI, 2012a; ECI, 2012) and including numerical soil dates associated with the BCWD at 10,000 Santa Monica Boulevard (Feffer-Geocon, 2012; Helms, 2012).

4.4 The San Pedro Sequence (SPS)

The oldest designated units evaluated in this study pertain to the San Pedro Sequence (SPS; Figure 7). The San Pedro Sequence includes from oldest to youngest the marine San Pedro Formation, marine Lakewood Formation, transitional marine to terrestrial sediments (marker unit Qeb), and terrestrial alluvial deposits (marker unit Qfob, E, and F). This study adopts marker units Qfob and Qeb as described by Parsons (2011). Units Qfob, E and F exhibit fining upward sequences suggesting that they were deposited terrestrially. Unit Qeb exhibits an abundance of clay and carbonate nodules and may represent a transitional unit between marine to terrestrial deposition locally. It is unknown whether the abundant carbonate in unit Qeb is pedogenic or due to some other secondary process but based on review of Soil Tectonics (2012) soil evaluation of unit Qeb at Beverly Hills High School (see LCI, 2012a), the carbonate in unit Qeb was produced by groundwater processes and not near surface pedogenic secondary weathering processes (i.e. Bk).

The contact between unit Qeb and underlying San Pedro Formation (Qsp), which occurs in areas where Lakewood Formation is not present, is described as stratigraphically conformable in many Parsons (2011) boring logs. This observation is one of the reasons to define the SPS to include a number of sedimentary units overlying the marine San Pedro Formation. However erosion surfaces do occur within SPS members above the Qeb. A relatively prominent erosion surface occurs between SPS and overlying CHD. In places, unit Qlw overlies the San Pedro Formation particularly in the region south of Santa Monica Boulevard and west of Century Park West. The northern limits of the Lakewood Formation likely represents an ancient shoreline in the Century City area. The unit consists primarily of silty sand and poorly graded sand, with local sandy silt and gravelly beds exhibiting relatively uniform lateral thickness (Parsons, 2011). Fining upward sequences were not observed to occur in the Lakewood Formation. Some basal members contain bivalve shell fragments (Parsons, 2011). The designation of the term Lakewood Formation for local marine units overlying San Pedro Formation was adopted herein as used by Parsons (2011). However, this unit likely does not correlate with marine Lakewood Formation identified south of the Cheviot Hills in the Los Angeles basin because it is generally considered to be approximately 200,000 years old or younger than the formation in the study area. For example, Mueller, (2002) indicates an age of the basal Lakewood Formation in the central Los Angeles Basin of approximately 330,000 years, and the "Lakewood Formation" in the study area is estimated to be greater than approximately 600,000 to 500,000 years old.

Crowder (1978) indicates that the Pleistocene-Pliocene contact occurs at a depth of approximately 500 feet in the region of the Cheviot Hills Oil Field located in the southern Cheviot Hills. This contact may approximately coincide with the base of the San Pedro Formation overlying Pico Formation, suggesting an approximate thickness of the marine Pleistocene sediments (Lakewood and San Pedro Formations) of 270 feet in the Cheviot Hills. Soper (1943) indicates a questionable Pleistocene-Pliocene contact at a depth of 900 feet within the Beverly Hills Oil Field located in the region of Beverly Hills High School. This depth suggests that the marine Pleistocene sediments (Lakewood and San Pedro Formations) may be 800 feet thick; however this total thickness may also include the marine Pico Formation which underlies the San Pedro Formation.

5.0 AGE DATA FOR THE DESIGNATED GEOLOGIC UNITS AND TERRACES

Numerical and relative ages were determined for relict surfaces and buried paleosols from a number of studies in the Century City area. Figure 1 provides the general location of the studies where the following studies were conducted:

- LCI (2012a) at Beverly Hills High School. This study includes soil/sediment numerical ages via Optically Stimulated Luminescence (OSL), Carbon-14; and evaluation of pedogenic soils by ECI (2012) and Soil Tectonics (2012b). These reports are provided in Appendix C of this report.
- Feffer-Geocon (2012) at 10,000 Santa Monica Boulevard. This study provided soil numerical ages conducted by Helms (2012) from a fault trench, which is provided in Appendix C of this report.
- Soil Tectonics (2012a) on Wilshire Boulevard. This report provides a soil numerical age for in a test pit along Wilshire Boulevard (Figure 9), which is provided in Appendix C of this report.
- Geocon (2013b) at the Westfield Century City Mall along the Avenue of the Stars. This report provides soil numerical ages evaluated by Helms (2013), which is provided in Appendix C of this report.

The results of all of these studies were synthesized stratigraphically to determine the sediment ages provided in this report. Hence, the age of some units provided in this report may vary from those provided in the referenced reports due to an understanding regarding the stratigraphic position in which the unit exists. In addition, soil pedogenic numeric age determinations provide minimum values for the actual age of sediments. The evaluated ages of units BrCW, BCWD1, BCWD2, CHD, and SPS are discussed individually below.

5.1 Age estimate of the Brown Canyon Wash deposits (BrCW)

The type section for the Brown Canyon Wash deposits (BrCW) occur within Brown Wash along the Avenue of the Stars in the region investigated by Geocon (2013b) along their cross section A-A' (Figure 9; Plate KGS-T1). Helms (2013) provided soil profile evaluations for four continuous core borings along this cross section all of which examined BrCW sediments overlying the younger member of the Benedict Canyon Wash Deposits (BCWD1). The soil ages determined by Helms (2013) were very consistent and determined that the local BCWD were laid down during approximately the past 10 to 20 kya, which are minimum ages. Immediately below the BrCW deposit occurs a soil identified by Helms (2013) that ranges in age from 25 to 50 kya, with an approximate average age of 38 kya. These sediments are considered the uppermost members of the BCWD1 (Figure 9).

The age of the BrCW deposits were also evaluated by ECI (2012) and Soil Tectonics (2012b) at Beverly Hills High School in LCI (2012a) Fault Trench FT-2. Both ECI and Soil Tectonics determined that the depth of BrCW age sediments occurred within Fault Trench FT-2 to depths of 5 to 8 feet, which is geomorphically located near the edge of BrCW deposits adjacent to the Cheviot Hills immediately to the west. An approximately 40 kya soil occurs beneath the BrCW deposits in LCI (2012a) Fault Trench FT-2 which is considered the uppermost member of the BCWD1 (Plate 1; Figure 9). Comparison of the soil stratigraphic studies by Helms (2013) along the Avenue of the Stars and by ECI (2012) and Soil Tectonics (2012b) at Beverly Hills High School indicate that within this study, the contact of the BrCW and BCWD1 commonly exhibits latest Pleistocene to Holocene sediments associated with BrCW, overlying an approximately 40 kya soil in the upper BCWD1. In summary, the BrCW were deposited between approximately 40 kya to the present time. However, the time boundary between BrCW deposition and cessation of deposition of BCWD1 is loosely defined and not connected directly to a geologic event other than the prominent erosion surface (unconformity) at the base of the BrCW in Brown Canyon.

5.2 Age estimate of the Younger Benedict Canyon Wash Deposits (BCWD1)

The type section of the younger member of the Benedict Canyon Wash Deposits (BCWD1) is provided by the soil stratigraphic study by Helms (2012) at 10,000 Santa Monica Boulevard for a fault investigation conducted by Feffer-Geocon (2012). This fault study involved an approximately 300 foot long trench extending to depths of approximately 25 feet (Plates KGS-FM1 and KGS-T5). The fault trench was excavated in a region where approximately 7 to 10 feet of BrCW had been removed (Plate KGS-T5), which essentially exposed BCWD1 at the current cut surface. Hence, the Surface Soil on Profile 1 identified by Helms (2012) estimated to be approximately 30 to 70 kya (50 kya average) is considered herein to represent the upper soil for the BCWD1 and the buried Qt-BC1 surface (Figure 9).

Based on review of the Helms (2013) report, the estimated cumulative age of the BCWD1 ranges from a minimum of approximately 113 to 235 kya (upper member/soil), to a soil age maximum of approximately 250 to 480 kya (basal members; see soil ages on KGS Plate T5). These ages include the soil age estimates for the inset channel in the 10,000 Santa Monica Boulevard fault trench, which exhibits cumulative soil ages of approximately 80 to 160 kya to the age of the BCWD1 and Qt-BC1 surface.

Based on these data, BCWD1 ceased deposition approximately 113 to 235 kya (upper member), and began deposition approximately 250 to 480 kya (basal members; see soil ages on KGS Plate T5). Hence, with reasonable rounding and averaging of age values, BCWD1 was deposited approximately between 170 to 370 kya. This age range also represents the time when flow occurred in the paleo-channel through Century City (Figure 19). These results are consistent with cessation of deposition of BCWD1 and development of the Qt-BC1 developing during sea level low stand associated with MIS 6 occurring approximately 150,000 years ago (Figure 19). BCWD1 continued deposition after abandonment of the paleo-channel, but was confined to Brown Wash and Moreno/Benedict Canyon washes.

5.3 Age estimate of the Benedict Canyon Wash Deposits (BCWD2)

A type section of the older member of the Benedict Canyon Wash Deposits (BCWD2) does not occur. Instead, the age, composition, and stratigraphic position of this unit are provided from numerous sites within the study area. The most distinctive aspect of the BCWD2 is the pedogenic soil that occurs at the top of the unit, which in this study is referred to as soil marker A (Figure 7). This soil was evaluated by Helms (2012) at the base of the fault trench at 10,000 Santa Monica Boulevard at the western end estimating a development age of 100 to 70 kya. This soil marker horizon exhibits a robust pedogenic soil that occurs at the surface on numerous preserved fan terraces Qt-BC2 as shown on Figure 14 and buried beneath BCWD1. Adding the cumulative ages of overlying soils associated with BCWD1 including the inset channel in BCWD1 provided by Helms (2012) indicates a cumulative maximum and minimum soil age of Soil Marker A of 580 to 320 kya respectively. This age correlates in the stratigraphic model proposed herein to the approximate age of the local Qt-BC2 fan-terrace surfaces.

Hence, it is proposed that the buried soil marker A generally correlates with the soil exposed on the Qt-BC2 surfaces (Plates KGS-T7, KGS-T5), which is the highest geomorphic preserved fan surface (terrace) in the study area. This proposal was supported by the findings in Soil Tectonics (2012a) indicating that the surface soil on the Qt-BC2 fan surfaces along Wilshire Boulevard and at Beverly Hills High School (see Figure 14) likely formed on the same alluvial fan member.

Additional age data were obtained for the Qt-BC2 fan-terraces. The minimum age of the Qt-BC2 surface is 80 kya based on relative development of its capping soil (Soil Tectonics, 2012a) as exposed in a test pit on Wilshire Boulevard (Figure 9) and in LCI (2012a) Fault Trench FT-2 at Beverly Hills High School. ECI (2012a) also described the same surface soil as exposed in LCI (2012a) Fault Trench FT-1 and nearby boring CB-3, and estimated a minimum age of 120,000 years. Tania Gonzalez (personal communication), who performed the soil age data report for ECI (2012a), indicated this information regarding the age of the upper most soil in LCI (2012a) in Fault Trench FT-1 and boring CB-3:

> *"Both horizons were truncated, so the age estimates are absolute minimum. The regressions indicate mean values of 68.5ka for the topsoil observed in FT-1 and 107ka for CB-3. My preference is that this surface is correlative with the 5e interglacial high-stand, and thus approximately 120ka. Capturing the full 95% of the data used to develop the age estimate regressions means that the minimum age for this surface is 22ka (FT-1) to 33ka (CB-3), whereas the maximum age is 220ka (FT-1) to 350ka (CB-3)."*

Soil Marker horizon A and associated BCWD2 "parent" sediments are correlated along Transect T5 (Plate KGS-T5) from beneath BCWD1 between Fault Zones A and F (Figure 16) to the soil exposed on Qt-BC2 in the region of LCI (2012a) Fault Trench FT-1 and boring CB-3. This model suggest that that the soil on the Qt-BC2 surface continued to develop as BCWD1 was deposited on top of Soil Marker A between Fault Zones A and F locally (Figure 16). Soil Marker A has been dated at numerous localities within the study area. The best cumulative soil age is provided by Helms (2012) within soil profile 1 in the western end of the Feffer-Geocon (2012) fault trench at 10,000 Santa Monica Boulevard (Figure 1). Here it is exposed at the base of the trench and is overlain by a nearly complete stratigraphic section of BCWD1. Helms (2012) determined a soil development age for soil marker A (his Buried Soil No.5) of 70,000 to 100,000 years, which infers that this soil was able to develop on a relatively stable surface for that period of time. Hence where Soil Marker A is buried typically beneath BCWD1, it generally exhibits a soil that required a minimum of 70 to 100 kya to develop. However, Helms (2012; Soil Profile No.1) determined a cumulative age for Soil Marker A of approximately 580,000 to 320,000 years, which includes the addition of age of the overlying BCWD1 (see Plate KGS-T5). Hence, where soil marker A is exposed on the local abandoned Qt-BC2 terraces, it may be as old as 580,000 to 320,000 years based on the stratigraphic model proposed.

Insufficient data exists to determine when BCWD2 began to be deposited. BCWD2 does contain multiple soils, however, soil marker horizon A is clearly the dominant soil in the unit. In addition, BCWD2 in the Cheviot Hills generally exhibits a gross fining upward sequence through the entire unit. These data suggest that the BCWD2 may have been deposited relatively fast and possibly over the course of just 150,000 years as shown on Figure 19.

5.4 Age estimate of the Cheviot Hills Deposits (CHD)

The type section for the Cheviot Hills Deposits (CHD) is provided by a soil stratigraphic analysis of continuous core CB-3 by ECI (2012a) as part of the LCI (2012a) fault investigation at Beverly Hills High School (Plate KGS-FM1 for location). Boring CB-3 included a relatively complete section of CHD from the base of the BCWD2 to the top of the San Pedro Sequence (SPS). Averaging a cumulative soil age based on numerical age dates provided in ECI (2012a) suggest that the oldest members of the CHD may be approximately 900,000 to 550,000 years old and including MIS stages 19 through 15 at a minimum (Figure 19).

5.5 Age estimate of the San Pedro Sequence (SPS)

The San Pedro Sequence (SPS) here refers to the marine San Pedro Formation (Qsp) and Lakewood Formation (Qlw) and conformable overlying dominantly terrestrial units (Figure 7). Based on the number of soil profiles and their development overlying the San Pedro Formation, ECI (2012a) estimated that the San Pedro Formation is at least (minimum age) 600,000 years old. As ECI (2012a) points out, the estimated age of San Pedro Formation of approximately 600,000 years is numerical, and may be 1,000,000 years old, which is consistent with the findings in this report. Overlying marker beds Qfob and Qeb, which were adopted from Parsons (2011), were estimated to be a minimum of 574,000 years old by ECI (2012) as correlated herein. In addition, it is unknown how much time is represented by the unconformity between units CHD and SPS among others. Based on the cumulative numerical soil ages estimated for the sediments overlying the SPS (i.e. BCWD and CHD), the upper members of the SPS are a minimum of 800,000 years old.

These ages are consistent with published age data for marine sediments in the Cheviot Hills. Hoots, (1931) indicates that early Pleistocene marine sediments occur in the Beverly Hills region (Cheviot Hills), hence an age between approximate 2 million and 670 kya. Rodda, (1957) indicated based on a paleontology and stratigraphic study in the southern Cheviot Hills an early Pleistocene age for his Anchor Silt which likely correlates to the San Pedro Formation as identified in Century City and the Baldwin Hills to the south. Regionally, Powell and Stevens (2000) provide a paleontological study of a relatively thick sequence of exposed San Pedro Formation in the eastern Los Angeles Basin region (Coyote Hills) indicating a late Pliocene to early Pleistocene age for the San Pedro Formation. Ponti (2008) indicates that the San Pedro Formation in the western Los Angeles Basin (i.e. Palos Verdes) is approximately 500 to 600 kya but that deposition was disrupted by local tectonics and therefore consistent with the findings of Powell and Stevens (2000).

6.0 FAULTING IN STUDY AREA

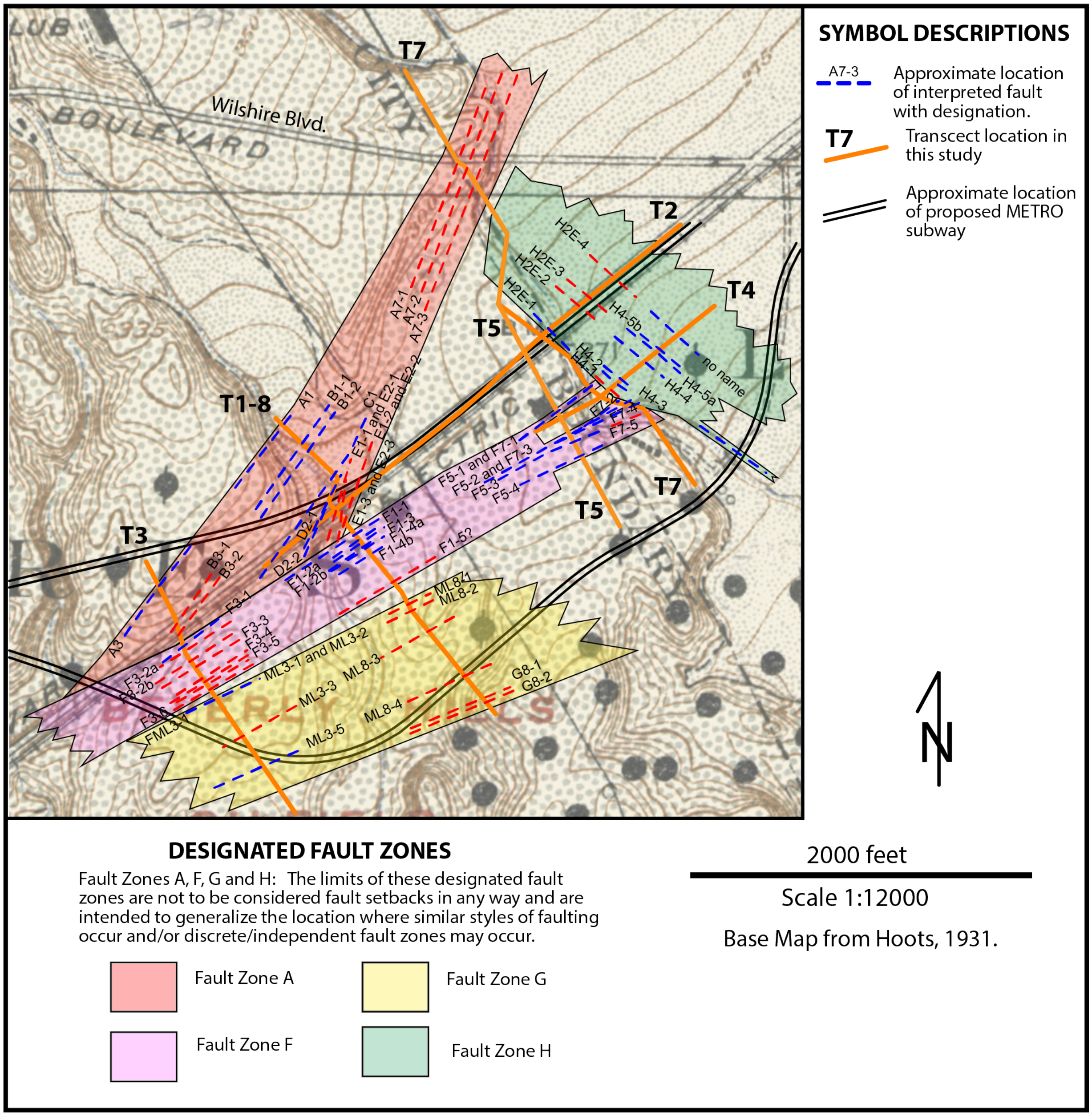
An indication of faulting was the apparent offset of soil horizons, soil properties, contacts and/or disruption of fining upward sequences. Groundwater levels were also utilized to assist in the identification of faulting at 9988 Wilshire Boulevard (TRC, 2008) within Fault Zone A. The vertical resolution of subsurface markers was qualitatively determined to range from three to five feet; however, this is in regions with reasonable boring and CPT separation density. In other words, the estimated vertical resolution of three to five vertical feet is based on the approximate average boring spacing (~170 feet), CPT spacing (~50 feet), and typical natural characteristics of dipping erosion and paleo-landscape surfaces. Hence, faults with this range of vertical displacement (separation) or less would be difficult to identify with the available data resolution. This is compounded by the observation that the Santa Monica Boulevard fault zone has dominantly exhibited strike-slip movement since the middle Pleistocene (KGS, 2011, 2012). Hence, identified faults may extend to shallower depths than indicated on the transect cross sections particularly if they exhibit offsets equal to or less than 3 to 5 feet.

Most of the faults shown on Plate KGS-FM1 were not positively identified since their inferred identification is based only on boring and CPT data, indicating that they are interpreted faults. As a result, no strike data was positively identified for the interpreted faults nor their termination depth. Only a few faults were positively identified in fault trenches as shown on Plate KGS-FM1. Hence, these are the only faults where strike data was obtained. These were identified LCI (2012a) in Beverly Hills High School, all of which were determined to be inactive. It should be pointed out that LCI (2012a) identified one inactive fault in their Fault Trench T3 that is not within a designated fault zone of this study. This suggests that some small-scale faults may occur throughout the study area not easily identified by continuous cores and CPT data. Some faults were identified in the continuous cores of Parsons (2011) by the identification of shear surfaces and changes in stratigraphic thickness across the shear surface. These data were utilized in this study to suggest the presence of a fault. E. Gath (personal communication) suggests that some seismite (an earthquake generated feature) occur in the area based on his evaluation of the "fault feature" in LCI (2012a) Fault Trench FT-3 at Beverly Hills High School. Gath suggests that the apparent offset of beds on FT-3 may have resulted from liquefaction processes. Hence, some small-scale offset structures may occur in the region that are related to seismic ground shaking but should not be considered "tectonic faults".

The new analysis identified four zones of faulting which are shown on Plate KGS-FM1 as Fault Zones A, F, G and H. Fault Zone A may be part of the Santa Monica Boulevard Fault Zone, however, this fault zone may also cross the West Beverly Hills Lineament and extend across the western Hollywood Basin to connect with the Hollywood Fault as shown on Figure 13. Fault Zones F and G are considered to be part of the Santa Monica Boulevard Fault Zone (SBMBFZ) as defined by KGS (2012; 2013) and herein. Fault Zone F is proposed to continue for several kilometers east of the WBHL as well as Fault Zone A. The northwest trending Fault Zone H may represent the northern extent of the Newport-Inglewood Fault Zone as shown on Figures 4 and 13.

The limits of the designated fault zones are not to be considered "fault set backs" or the limits of possible faulting in any way. Instead, the zones are intended to provide some insights on the anticipated style and general trend of zones of faulting that will likely be identified during future studies and thus provide a useful tool for future work. Fault activity is discussed in the next section. The location and style of faulting for each zone are discussed below.

Figure 17: Preliminary fault zone map with natural topography from Hoots, 1931.



6.1 Fault Zone A

Fault Zone A trends northeast and away from Santa Monica Boulevard near the north end of Transects 3 and 1. Faults associated with Fault Zone A continue toward the northeast and along the mapped scarp for the Santa Monica Fault Zone of Dolan and Sieh (1992). The fault zone extends to the El Rodeo K-12 School. The total vertical apparent offset across Fault Zone A ranges from approximately 50 to 60 feet near Santa Monica Boulevard and the Avenue of the Stars (western end) to 80 to 90 feet at its eastern end at the El Rodeo K-12 School. The increase in apparent reverse displacement (separation) may be an artifact of measurement across a zone where older sediments dip on the west and are generally horizontal toward the east. Alternatively, an increase in apparent reverse displacement toward the east may suggest that the fault zone extends across the West Beverly Hills Lineament and into the western Hollywood Basin (Figure 13).

There is no geomorphic expression of Fault Zone A across the modern Benedict Canyon Wash (Moreno Creek) fan surfaces east of the El Rodeo school, implying that 1) fan deposition rates greatly exceed the fault offset rates, 2) the fault turns 45 degrees northerly up the Moreno Creek channel, or 3) Fault Zone A is inactive. If Fault Zone A does trend easterly across the fan as proposed herein, it has not generated an observable groundwater barrier. At Beverly Hills High School, an approximately 20,0000 year old soil was buried by only five feet of Holocene age sediments. This suggests a locally low sedimentation rate associated with the Moreno Creek fan system and sufficiently low to have difficulty to bury an actively growing fault scarp. If Fault Zone A bends northerly (left-ward), it should be generating a depression (pull-apart basin) which is also not observable in the geology of landscape. If Fault Zone A is inactive since before the establishment of Moreno Cree, all of these problems disappear.

6.2 Fault Zone F

Fault Zone F trends northwest sub-parallel to Santa Monica Boulevard and is likely the dominant zone and mode of faulting occurring at a minimum between the Mormon Temple and Beverly Hills High School (Figure 1). Hence, this fault zone likely continues further west of the Mormon Temple and further east than the West Beverly Hills Lineament as shown on Figure 13. Fault Zone F bifurcates (merges) into the northeasterly trending Fault Zone A in the general region of the intersection of Transect 1 and Transect 2 (intersection of Santa Monica Boulevard and The Avenue of the Stars). A strand of Fault Zone F (F5-3 on Plate KGS-FM1) was positively identified by LCI (2012a) in their Fault Trench FT-5, which provided confirmation that Fault Zone F extended to Transect 7 as proposed by KGS (2012) and the northwest strike of the zone. A fault investigation by Geocon (2013b) for the Westfield Mall properties along the Avenue of the Stars determined that most interpreted fault strands associated with Fault Zone F are inactive.

Fault Zone F exhibits primarily steeply north-dipping faults (55 to 70 degrees) with normal apparent displacement ranging from approximately 70 to 85 feet. Fault bounded block rotations and flower structures at various scales occur within this fault zone. A fault-created structural synform occurs along Fault Zone F east of the Avenue of the Stars defined by southward tilting north of the fault zone and a gentle northward dip south of the fault zone of BCWD2 and older sediments. West of The Avenue of the Stars, sediments between Fault Zones A and F dropped relative to sediments to the north and south creating a structural "depression" (Figure 16). The ancient Benedict Canyon Wash flowed toward the southwest through Century City likely due to the structural depression (Figure 15).

The top of the San Pedro Formation across the fault zone does not exhibit net reverse displacement (i.e. north side up). This is observed on Transects T1, T3 and T7 (Plates KGS-T1, KGS-T3 and KGS-T7). In addition, and as discussed in KGS (2011, 2012), the preserved fan terraces (Qt-BC2) in Century City also do not exhibit a net reverse dip-slip offset. These data indicate that Fault Zone F is dominantly a strike-slip fault. However, it is currently unknown whether the zone exhibited left- or right-lateral displacement. Various lines of evidence suggest the fault zone could be either (inconclusive). It is proposed that Fault Zone F represents faults active during the middle Pleistocene that connects at depth with the re-activated Santa Monica Fault North of Wright (1991) and may extend east of the West Beverly Hills Lineament several kilometers (Figures 4 and 13). It is also proposed that Fault Zone F steps over to the North Salt Lake Fault near the boundary of the San Vicente and Salt Lake Oil Fields and that the North Salt Lake Fault Zone was also re-activated in the middle Pleistocene. These fault zones may have accommodated strike-slip motion (likely left-lateral) during the middle Pleistocene associated with westward movement of the Western Transverse Ranges relative to the northern Los Angeles Basin.

At this time the nature of the eastern intersection of Fault Zone F and Fault Zone H (SMDFZ) is unknown primarily due to a lack of sufficient subsurface data for Fault Zone H. However, interpreted strands of Fault Zone H are identified both north and south of Fault Zone F suggesting that it may be younger.

6.3 Fault Zone G

Fault Zone G is located south of Fault Zone F and represents a series of relatively small-scale, widely spaced interpreted faults that may trend sub-parallel to the SMBFZ. Similar faults were identified by Parsons (2011) in their geophysical analysis (seismic reflection lines), however, they did not show these faults on their fault map. No strike data yet exists for any of these faults, and none of them have been positively identified. The faults identified in Fault Zone G are based on a more detailed review of the Parsons (2011) subsurface data along Transects 1 and 3 than was conducted for KGS (2012) and includes an independent review of the geophysical seismic lines (Legg Geophysical, 2012a and 2012b). The data utilized to interpret these faults (i.e. Geophysical and/or boring-CPT) are shown on Plate KGS-FM1. The southeastward edge of Fault Zone G is unknown and essentially extends to the southern limits of the study area suggesting that it may extend further south than the study area.

It is also possible that the proposed small-scale faults identified in Fault Zone G are simply common to the area. An example of this is the small-scale fault identified by LCI (2012a) in Beverly Hills High School (Fault Trench FT-3), which they determined to be inactive. In addition, small-scale faults with normal separation were recently identified (confidential correspondence) in an excavation at the Hillcrest Country Club located approximately one kilometer south of Beverly Hills High School.

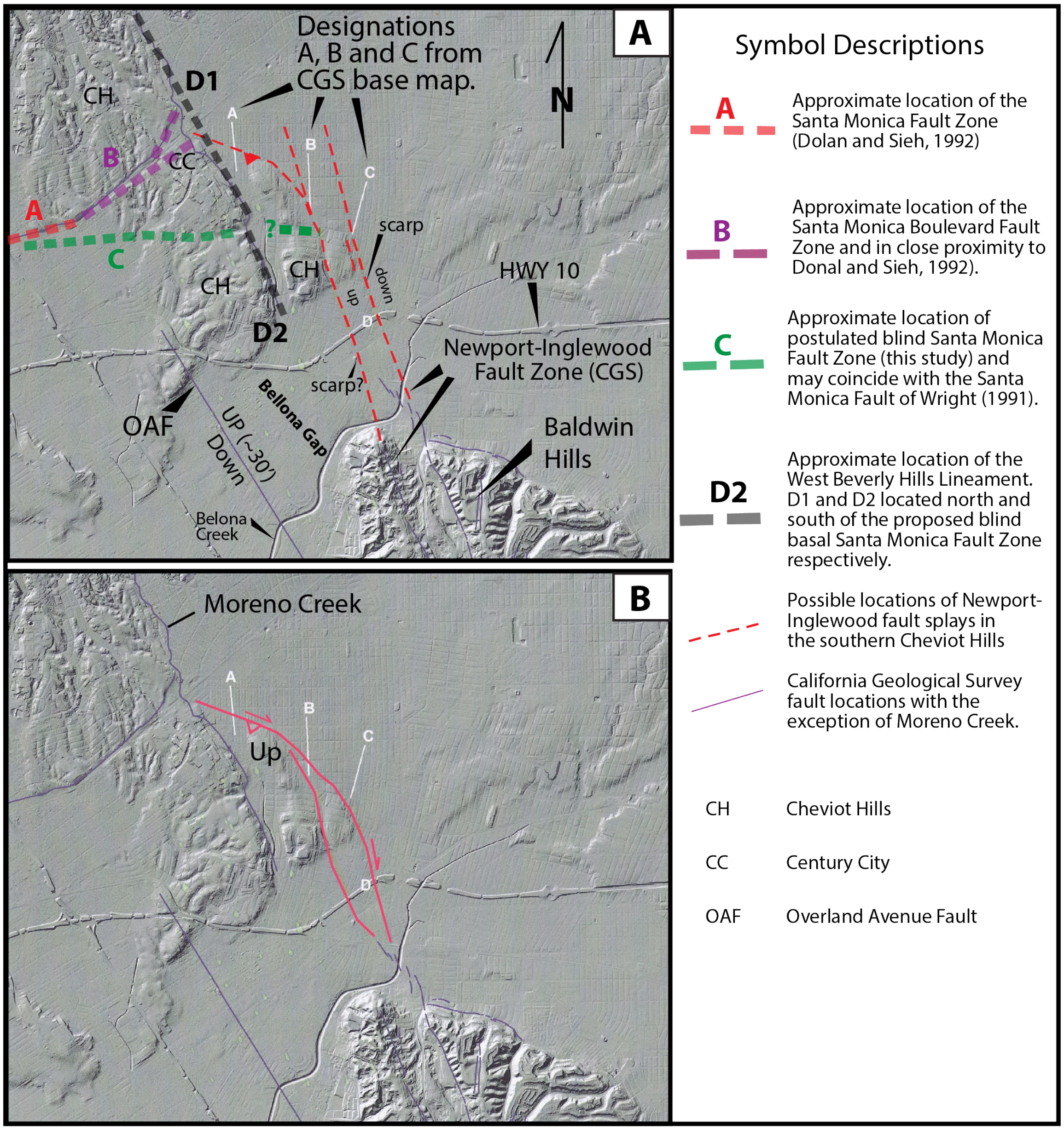
6.4 Fault Zone H

Fault Zone H is a series of northwest striking interpreted faults (~N50-60W) located in the general area along and east of South Moreno Drive. None of these faults have been positively identified; hence no strike data exists. However, apparent down to the east displacements of the top of the San Pedro Formation along Transects 2, 4 (Plates KGS-T2, and T4), and along LCI (2012a) cross section C-C' suggests a continuous zone of faults trending approximately N50-60 west. These faults are similar to those identified as the West Beverly Hills Lineament Fault Zone (WBHLFZ) by Parsons (2011) but with some primary differences (compare Figures 6 and 17). Fault Zone H strikes more northwesterly, is located more easterly, and does not trend parallel to the geomorphic feature that was labeled as the West Beverly Hills Lineament (WBHL). It is unclear which faults identified on Transects 2 and 4 connect with each other. One possibility is shown on Plate KGS-FM1; however, these faults may trend (correlate) in a more northwesterly trend than shown.

Fault Zone H may connect to the south to southeast with strands of the Newport Inglewood Fault Zone on the eastern side of the southeastern Cheviot Hills as shown in Figures 4,13 and 18. The eastern extent of Fault Zone H is unknown. However, if Fault Zone H represents the northern limits of the Newport-Inglewood Fault Zone as proposed herein, then it may extend approximately a mile east if proposed faults by Erickson and Spaulding (1975), Wright (1991) and KGS (2012) occur (Figure 13).

The displacement across various strands within Fault Zone H is down to the east; however, the dip direction of these faults is currently unknown. In other words, Plate KGS-FM1 shows the faults dipping toward the east exhibiting an apparent normal dip-slip offset; however, these faults could dip toward the west and exhibit apparent reverse dip-slip displacement. This second scenario may be more plausible because it would account for an uplift mechanism of the eastern Cheviot Hills, and the development of the northward trending anticline discussed (KGS 2012; Figure 11). In fact, the small set of hills in the southeastern Cheviot Hills and east of the WBHL may have resulted from a restraining bend in the northern Newport Inglewood fault based on this scenario (Figures 13 and 18).

Figure 18: Proposed location of strands of the Newport-Inglewood Fault Zone into the southeastern Cheviot Hills (Modified from KGS, 2012). Base map provided by the California Geological Survey (LIDAR Data).



7.0 FAULT ACTIVITY AND DENSITY OF EXISTING DATA

A preliminary and tentative evaluation of fault activity was conducted for all the interpreted fault strands along each transect. As discussed earlier in the report, the estimated vertical error of dip-slip apparent offset across interpreted faults is in the range of 3 to 5 feet. Also, if a fault demonstrates dominantly strike-slip motion, which most are proposed, it requires greater displacement across that fault prior to achieving a vertical separation of 3 to 5 feet or greater for gently dipping sediments. Regions of ongoing deposition, progressively younger sediments will exhibit progressively less vertical separation due to experiencing fewer displacement events, which also contributes to difficulties estimating fault activity. Hence, the upward termination depth of many faults becomes more difficult to identify when they extend into progressively younger sediments and demonstrate primarily strike-slip movement.

The preliminary assessment of fault activity shows that in general, interpreted faults in areas with a relatively dense subsurface data set (borings and CPTs, fault trenches) were most commonly identified as likely inactive. In contrast, interpreted faults identified as activity unknown occur in regions with a relatively less dense subsurface data. Hence, where sufficient data exists, most evaluated faults appear to most likely be inactive. This observation is supported by recent fault investigations to satisfy State of California Fault Hazard Zone criteria (AP Act of Bryant and Hart, 2007) across various strands of Fault Zone F (LCI, 2012a) and Geocon (2013b) that determined them to be inactive.

Interpreted fault activity was designated as likely inactive or activity unknown, none were confirmed to be Holocene active. These faults are shown as blue and orange respectively on the fault map (Plates KGS-FM1) and Transects (Plates KGS-T1, -T2, -T3, -T4, -T5 and –T7). Note that the fault activity color scheme is not shown on any figures of this report. A fault was identified as likely inactive if a stratigraphic structure (i.e. marker beds, basal erosion surface) of at least latest Pleistocene in age appeared continuous over a deeper fault. These faults typically occur in areas of the study with relatively dense subsurface data. Faults colored orange on the fault map and transect plates do not have sufficient data to provide a preliminary activity assessment, or these interpreted faults extend very close to the surface possible in late Pleistocene age sediments. The activity level of all the interpreted faults was done independently on each transect; hence the findings along one transect did not contribute to the designation along another transect within the same fault zone. It should be mentioned, that a relatively dense subsurface data set provided by Geocon (2013b; their Cross Section B-B') along Century Park West evaluating Fault Zone F was not utilized in this study. Hence, it is possible that many of these faults currently designated as activity unknown may change to likely inactive if these data were evaluated fully. Geocon (2013b) determined that faulting within Fault Zone F along Century Park West and The Avenue of the Stars are inactive; which is consistent with LCI (2012a) determining that strands of Fault Zone F in Beverly Hills High School are inactive. Hence, it appears likely that Fault Zone F is inactive. Based on all the age data, Fault Zone F is determined to have become inactive sometime between 250,000 to 200,000 years ago (Figure 19).

Most strands of Fault Zone A near the intersection of Transects T1 and T2 are designated as likely inactive (blue). This conclusion is primarily based on the evaluation that the base of the Brown Canyon Wash deposits (BrCW) overlying Benedict Canyon Wash Deposits younger (BCWD1) is not offset. Although Geocon (2012b) did not evaluate interpreted faults associated with Fault Zone A, they identified this contact as a marker horizon crossing over all strands of Fault Zone F (this study) without displacement. They estimated that the sediments overlying the erosion surface at the base of the BrCW at approximately 40,000 years, and that soils immediately underlying the erosion surface to be approximately 120,000 years old. In this study, this erosion surface at the base of the BrCW was correlated further north and east along Transects 1 and 2 (Plates KGS-T1, KGS-T2) respectively over all interpreted strands of Fault Zone A without apparent disruption. In the northeastern portion of Fault Zone A in the region of Transect 7, subsurface data was not sufficient to suggest inactivity; hence these strands are designated as activity unknown (red).

All interpreted faults within Fault Zone G are designated as activity unknown (red) due to a relatively less dense subsurface data set. Also, interpreted faults in this zone generally exhibit relatively small apparent dip-slip displacements increasing the difficulty in knowing whether or not these faults even exist, or what their activity level is.

Interpreted faults within Fault Zone H are designated as mostly inactive along Transect 4 and the one interpreted strand along LCI (2012a) on their Cross Section C-C'. This designation was supported by the identification of members of BCWD1 that may not be displaced. However, there is sufficient ambiguity in the local stratigraphy to allow for these faults to extend to shallower depths along Transect 4. Interpreted Fault Zone H faults along Transect 2 are designated as activity unknown due to a lack of sufficient subsurface data.

8.0 QUATERNARY GEOLOGIC HISTORY

This study evaluated the stratigraphic history of near surface sediments (approximately upper 200 feet) in the Century City area within the Cheviot Hills. Sediments range in age from approximately one million years old to the present time and exhibit a transition from marine to terrestrial deposition that likely occurred around 800,000 years ago. Local marine sediments include the San Pedro Formation (Qsp) estimated to be about one million years old locally and overlying shallow marine sands associated with the Lakewood Formation (Qlw). However, the local Lakewood formation name used herein and adopted from Parsons (2011) likely does not correlate with much younger type section Lakewood Formation identified to the south in the Los Angeles Basin.

Marker bed unit Qeb of this report and adopted from Parsons (2011), which is composed dominantly of clay and exhibits abundant secondary carbonate, may represent a transition unit from marine to terrestrial. Hence, possibly deposited in brackish water. Marker bed unit Qfob, which overlies unit Qeb, is the first clear terrestrial unit. Qfob exhibits abundant coarse sediments and secondary carbonate. The contact between the Qfob and Qeb is a relatively strong marker contact across the study area. Above unit Qfob is a series of structurally conformable terrestrial sediments that contain soil marker horizons E and F of this study. Fining upward sequences are common within these deposits as well as secondary pedogenic parameters (oxide deposits, and carbonate). Units Qsp, Qlw, Qeb, Qfob and soil marker horizons E and F were grouped together within this study as the San Pedro Sequence. The upper contact of the San Pedro Sequence is marked by a relatively robust erosion surface at the base of the overlying terrestrial Cheviot Hills Deposits (CHD). In general, the lower members of the CHD are relatively coarse grained and fine upwards to a relatively thick upper member zone dominated by fine-grained sediments (clay and silt). The fine-grained upper members may have been deposited in a boggy area or as wide spread flood plane deposits possibly similar to boggy sediments deposited in recent times in Bellona Gap immediately south of the Cheviot Hills. The CHD is estimated to have ceased deposition around Marine Isotope Stage 14 (MIS 14; Figure 19); however this age is not well constrained.

The upper contact of the CHD is marked by a relatively robust erosion surface associated with the inception of deposition of the older member of the Benedict Canyon Wash Deposits (BCWD2). The base of the BCWD2 is dominated by very coarse grained sediments and the unit fines upwards to terminate at Soil Marker horizon A, which is estimated to have developed sometime during MIS 11 to 10 (Figure 19). BCWD2 may be the first local unit that was dominated by alluvial fan sediments shed from the local Santa

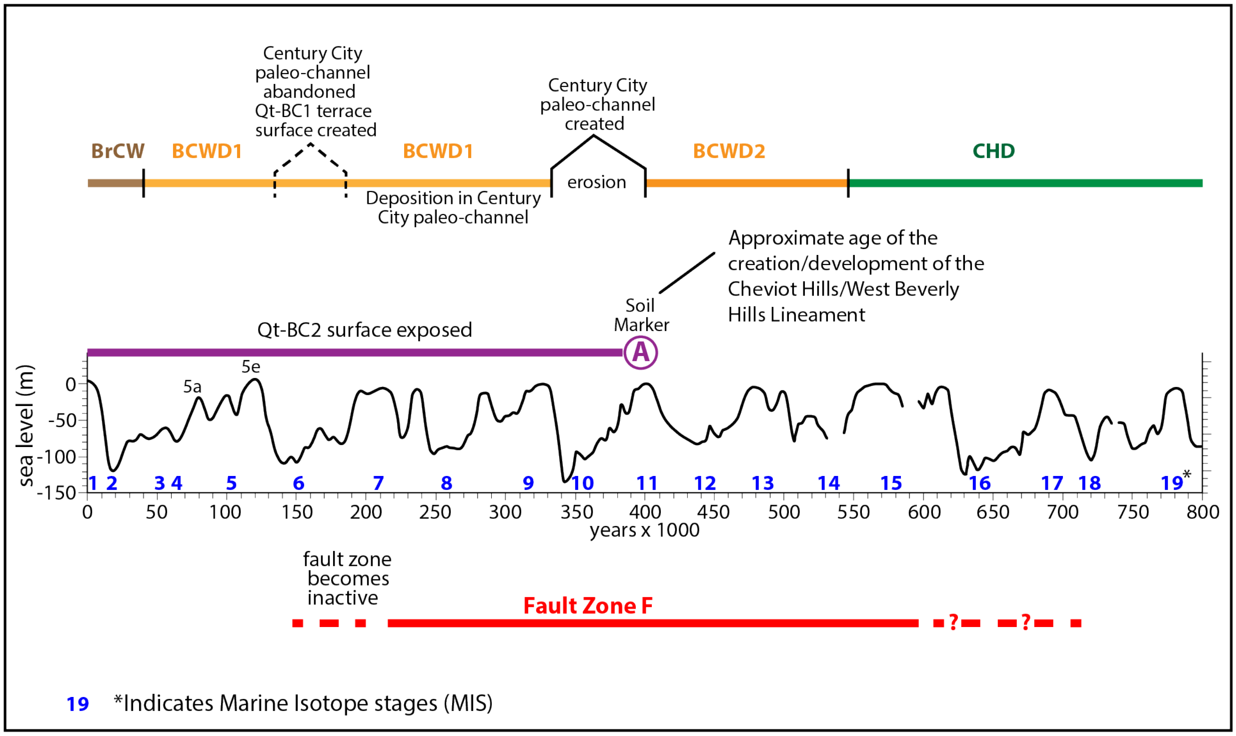
Monica Mountains to the north. It was deposited as faulting along the Santa Monica Boulevard Fault Zone occurred, however, sedimentation was able to deposit across the fault zones locally allowing for thicker sections of BCWD2 to be deposited within the down-dropped area between Fault Zones A and F in Century City. Faulting along the Santa Monica Boulevard Fault Zone may have begun around 700,000 to 550,000 years ago and was occurring as a north-northwest trending open anticline developed in the southern Cheviot Hills causing the hills to uplift. Uplift may have also occurred in the northern Cheviot Hills as well. Near the termination of deposition of BCWD2, uplift of the Cheviot Hills was sufficient to produce preserved fan-terraces in the region (Qt-BC2), which is estimated to have develop around MIS 11 to 10 (~400,000 to 350,000 years ago; Figure 19). This coincides with the age of Soil Marker horizon A. This event generally coincides with the development of a paleo-channel that flowed south-southwest through the Cheviot Hills which developed due to a combination of uplift and erosion into the now elevated Cheviot Hills, and down-dropping between Fault Zones A and F that produced a low standing pathway through the hills. The creation of the abandoned Qt-BC2 surfaces associated with uplift of the Cheviot Hills is proposed to represent the time of the development of the West Beverly Hills Lineament, which was created dominantly by erosion as the hills rose relative to the surrounding area. The mechanism for the uplift of the Cheviot Hills (creation of antiform) is proposed to be associated with transpression and local restraining bends along the Newport-Inglewood Fault Zone (NIFZ) in addition to regional uplift in the northern Los Angeles Basin that extends south of Santa Monica Boulevard west of the WBHL.

By definition, the older member of the Benedict Canyon Wash Deposits (BCWD1) was deposited within the south-southwest flowing paleo-channel and below the now abandoned Qt-BC2 fan-terrace surfaces in the Cheviot Hills. Hence, at times, it may have flowed in the paleo-channel flowing through the Cheviot Hills and along the eastern side of the Cheviot Hills along the newly developed WBHL. The paleo-channel was likely abandoned during approximately MIS 6 (190,000 to 140,000 years ago), which was a time of relatively low sea level and associated incision/erosion. Accordingly, this is estimated to be the period of time that coincides with the abandonment of the alluvial fan lobe associated with BCWD1 deposition (older members) located on the southwest flanks of the Cheviot Hills (Figure 15). The younger member of BCWD1 was subsequently confined to the fan associated with Moreno Creek along the eastern side of the Cheviot Hills and within drainages in the Cheviot Hills that still exist today. The younger upper members of the BCWD1 (<MIS 6) were deposited during relative sea level high stands associated with MIS 5. Erosion associated with relative low sea level stands of MIS 10 and 6 occurring approximately 350,000 and 150,000 years ago respectively likely represent the periods of time when local deep erosion led to the development of the West Beverly Hills Lineament and the antecedent nature of Moreno Creek in the southeastern Cheviot Hills (Figure 11),

The relatively robust erosion surface at the base of the Brown Canyon Wash sediments (BrCW) may have formed during the relatively low sea level stand associated with MIS 4 (~70,000 to 60,000 years ago). Hence, the cessation of deposition of the younger member of BCWD1 may have occurred during MIS 4 prior to deposition of the BrCW.

Fault activity on Fault Zone F, and possibly Fault Zone A as well, likely ceased around 200,000 years ago. This conclusion however, does not suggest that the Santa Monica Fault Zone to the west as identified at the VA Hospital is inactive because the relationship between the Santa Monica Boulevard Fault Zone and Santa Monica Fault Zones has not been established.

Figure 19 Estimated timing of deposition of designated units and key preserved fan-terrace surfaces in the Century City area since the mid-Pleistocene plotted via Marine Isotope Stages (MIS).



9.0 REPORT CONCULSIONS

Kenney GeoScience has made the following conclusions based on all the referenced data regarding potential locations and activity of seismic deformation (faulting, folding, etc.) in the Century City area.

- Numerically dated soils (sediments) are correlated throughout Century City to assist in future investigations.

- A revised fault map is provided for the Century City area to assist in future development and geologic investigations. These faults have been interpreted from the various data sources, and other than strands in Fault Zone F, have also never been physically seen (i.e. within fault trenches).

- A late Quaternary geologic history for the Cheviot Hills provides an improved understanding of the local stratigraphy, and timing and scale of local deformational structures and sedimentary units in the Cheviot Hills. This stratigraphic history model can be modified by future investigations.

- As interpreted here, the Santa Monica Boulevard Fault Zone dips steeply toward the north and exhibits primarily lateral displacement (KGS, 2011; KGS, 2012). This fault zone includes Fault Zones A, F and G of this study (Figure 6). However, northeast trending Fault Zone A located at the southern Los Angeles Country Club may be an independent zone. If that is the case, it may display a different style of slip.

- The data suggest that Fault Zone F of the Santa Monica Boulevard Fault was active during late to middle Pleistocene and extended eastward across the West Beverly Hills Lineament along the southern boundary of the Hollywood Basin.

- Several fault strands interpreted by Parsons (2011) as part of their proposed northwest striking West Beverly Hills Lineament Fault Zone were re-interpreted as faults associated with the Santa Monica Boulevard Fault Zone (Fault Zone F; KGS, 2012). This was confirmed by a fault investigation conducted by LCI (2012a).

- Some faults interpreted by Parsons (2011) within their West Beverly Hills Lineament Fault Zone along Santa Monica Boulevard (Transect T-2) and Durant Street (Transect 4) are identified within Fault Zone H of this study; however, the strike of Fault Zone H is more northwesterly and not parallel with the West Beverly Hills Lineament. This fault zone could connect to the Newport-Inglewood Fault Zone.

- Subsurface stratigraphy across the Santa Monica Boulevard Fault Zone along Santa Monica Boulevard indicates that net reverse faulting (up to the north) has not occurred in Century City.

- A series of small-scale faults are interpreted south of Fault Zone F extending the southern limits of the study area near Constellation Boulevard (Fault Zone G; Figure 6). Some of these faults are interpreted primarily from geophysical data (seismic refraction) provided by Parsons (2011), which identified some of the faults but inexplicably did not plot them on their fault map. Legg (2012a, 2012b) analysis of the Parsons (2011) data interpreted numerous faults within Fault Zone G, which are incorporated into the revised fault map. Some faults within Fault Zone G are based primarily on re-interpretation of Parsons (2011) boring log data.

- It is proposed that Fault Zone A likely continues across the West Beverly Hills Lineament and into the western Hollywood Basin several kilometers (Cross Fault shown on Figure 10). Based on this model, Fault Zone A may connect with the Hollywood Fault Zone.

- Based on warping of preserved fan surfaces that are likely 350 to 200 kya in the northern Cheviot Hills, the Hollywood Fault Zone may extend across the northern West Beverly Hills Lineament and into the northern Cheviot Hills.

- No conclusive evidence has been published that <u>any</u> faults in the Century City area (area of study) are active Holocene structures. Fault Investigations by LCI (2012a) and Feffer-Geocon (2012) concluded that numerous proposed WBHL faults interpreted by Parsons (2011) are inactive, and that many of their interpreted fault strands within this zone do not exist at least in near surface late Pleistocene sediments that are hundreds of thousands of years old. In addition, LCI (2012a) and Geocon (2013b) provide strong evidence that strands of Fault Zone F, which is the dominant zone of faulting within the Santa Monica Boulevard fault zone are not active. However, to date, no fault activity studies have been conducted on the interpreted faults within Fault Zones A, G and H.

- As originally proposed by Hoots (1031), north-northwest trending late Pleistocene antiformal folding is occurring in the southern Cheviot Hills south of Santa Monica Boulevard. This folding may be active; hence may potentially affect proposed subway stations on either Santa Monica or Constellation (also see KGS, 2011). The fold axis trends parallel to the WBHL and Newport-Inglewood Fault Zone approximately along the Avenue of the Stars, which coincides with the highest elevations of the Cheviot Hills south of Santa Monica Boulevard. Pleistocene age folding was originally proposed in the Cheviot Hills by Hoots (1931). The Qt-BC2 terrace fan surface exposed in the local Cheviot Hills that is a minimum of 200,000 years old and may be as old as 400,000 years is also deformed by the fold. The fold deforms the top of the San Pedro Formation and two overlying marker horizons (Qfob and Qeb) approximately equally to the preserved fan surfaces suggesting that the folding initiated during the middle to late Pleistocene (i.e. ~600 kya). This provides a preliminary minimum uplift rate of approximately 0.04 to 0.07 mm/year. The eastern limb of the fold extends across the West Beverly Hills Lineament. The antiform has not been documented north of Santa Monica Boulevard but may represent an east dipping monocline in that region. These findings indicated that the geomorphic West Beverly Hills Lineament was dominantly produced by uplift associated with uplift-folding and ongoing erosion in the eastern Cheviot Hills, and not near surface faulting (fault scarp). However, the fold may be the northern extension of an antiform identified in the Baldwin Hills (Tieja, 1926) and crossing Belona Gap. Hummon et al. (1994) also shows a gentle northwest trending fold in early Quaternary gravels extending from the Baldwin Hills north to the southern Cheviot Hills consistent with the findings in this report. It is proposed that the north-northwest striking antiform resulted from transpression associated with tectonic kinematics adjacent to the approximately parallel Newport-Inglewood Fault to the east.

- Parsons (2011) presumed that most sedimentary units evaluated exhibited essentially horizontal bedding, which led to the false positive identification of numerous faults within their West Beverly Hills Lineament - Newport-Inglewood Fault Zone particularly along Constellation Boulevard and Transect 4 along Durant Drive. This also indicates that they had not identified the north trending antiform in the southern Cheviot Hills. However, Parsons (2012) provided structure contour maps of the top of the San Pedro Formation of the interpreted antiform showing the folding at the proposed Constellation station site.

- The Benedict Canyon Wash has played a significant role in the Cheviot Hills region since the late Quaternary. Today, it is a northwest-southeast trending drainage called Moreno Creek that has contributed significantly to the erosional and depositional patterns that contributed to the slope that Dolan and Sieh (1992) labeled as the West Beverly Hills Lineament. However, during the late Pleistocene, the Benedict Canyon Wash had branched to flow south-southwest across the northern edge of Century City and through the Cheviot Hills along portions of the current Brown Wash, and along the WBHL toward the southeast. Parsons (2011) did not identify the Benedict

Canyon Wash Deposits (i.e. BCWD1) as a locally significant stratigraphic unit. Relatively older members of the BCWD (unit BCWD2) of this study are the surficial sediments on the prominent preserved fan terraces in the local Cheviot Hills. The capping soil on these surfaces is estimated to be 400,000 to 350,000 years old (soil marker A).

It should be noted that additional investigations are currently underway by private parties that have been negatively affected by the Metro studies. Namely, a fault investigation by Geocon at 9900 Wilshire Boulevard involving fault trenching, continuous boring cores, and CPT that investigates interpreted faults within Fault Zones A and H. This report was completed recently but there was insufficient time to incorporate their findings in this study. This is an important study because Fault Zones A and H have not been positively identified near the surface via fault trenching, hence, their activity level has not yet been evaluated in detail. Kenney Geoscience provided Geocon an analysis of the subsurface stratigraphy and structure extending across the 9900 Wilshire Boulevard property to assist in their study (Transect 7). Unlike the Metro studies, this investigation is subject to regulatory oversight and review to the satisfaction of the City of Beverly Hills as part of its standard permitting process. The City of Los Angeles approved their fault investigation report, which included proposed fault set back zones bounding strands of Fault Zone A Geocon determined to be active. The Geocon (2014) conclusion of active faults to the northwest of the 9900 Wilshire property (Fault Zone A in this study) is currently under study on the El Rodeo campus.

The findings and conclusions of this report are intended to provide a framework for the local structure, structural history and stratigraphic history of the Century City and Cheviot Hills area. Additional data provided by future studies will certainly modify the findings provided herein.

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APPENDIX A GLOSSARY OF SELLECTED GEOLOGIC TERMS

A horizon - Organic rich soil horizon.

active fault - "An active fault is Defined by the State of California Mining and Geology Board as a fault that has “had surface displacement within Holocene time (about the last 11,000 years)” (see Appendix B, Section 3601)."

age data - "A numerical age estimate measurement or proxy measurement for a geological process. Examples include the time for the development of a pidgin soil, age when a pedogenic soil was buried, age of initiation or cessation of folding, uplift, or faulting, and the age of depositional unit or marker beds. the formation or deformation of a geologic or pedologic unit. "

age dating - "Using any of several techniques to estimate the age of a particular geologic unit or structure. Typical Some examples include numerical age data come from the dating of radiocarbon (Carbon-14), pedogenic soil development or and surface exposure techniques."

Alluvium - "Surficial sediments of poorly consolidated gravels, sand, silts, and clays deposited by flowing water."

anticline - A fold that is convex in the direction of the youngest beds in the folded sequence.

antiform - In the form of an anticline. See Anticline.

apparent offset - The amount of offset measured in a trench or in a stream bed may not be the actual amount of offset. The orientation of the trench or stream to the fault effects how much of the actual offset is measureable.

argillic horizon - A soil horizon where secondary clay has been transported or translocated into the sediment over time.

back limb - "The less-steeply dipping limb, or flank, of an asymmetrical fold. "

basal erosion surface - A surface at the bottom of a package of sediments deposited after a period of erosion has occurred. The surface that was cut during a period of erosion.

basal member - The bottom member of a depositional package or sequence.

Bk horizon - see carbonate horizon

blind fault zone - A fault zone whose extent does not reach the surface of the earth.

boring data - Information obtained from any of several drilling techniques about the subsurface geology.

Bt horizon - see argillic horizon

capping soil - the uppermost soil associated with a fining upward sequence and/or a preserved fan-terrace surface.

carbon 14 - "Radiocarbon, or 14C, a radioactive isotope of carbon. Used in Radiocarbon or Carbon 14 dating. Carbon 14 dating depends on the fact that 14C is constantly being created in the atmosphere by cosmic rays. The resulting radioactive carbon dioxide is incorporated into plants by photosynthesis, and animals acquire 14C by eating the plants, or by eating other animals. When the animal or plant dies, it stops exchanging carbon with its environment, and from that point the amount of 14C it contains begins to reduce, as the 14C undergoes radioactive decay. Measuring the amount of 14C in a sample from a dead plant or animal, such as piece of old wood, or a fragment of bone, provides information that can be used to calculate when the animal or plant died."

carbonate - "Calcium Carbonate, CaCO3."

carbonate horizon - A soil horizon where Calcium Carbonate (carbonate) has been added to the horizon in large enough amounts that it visibly coats most clasts and or has produced many individual nodules of carbonate.

compressional fault - A trust or reverse fault. Compression causes relative movement in which rocks of lower stratigraphic position are pushed up and over higher strata. They are often recognized because they place older rocks above younger.

continuous core boring - "Boring technique where a coherent, intact geologic sample is retrieved, documented, defined and used to correlate across an area."

CPT data - "Data gathered using the Cone Penetrometer Test (CPT), where electronic friction cones and piezocone penetromoters are pushed into the earth surface at constant velocity in order to measure the resistance and pore pressure, thereby giving a lithologic interpretation of the subsurface stratigraphy."

cross section - A diagram showing the features transected by a vertical plane. Created based on interpretation of subsurface data collected by various methods.

deformation - "A general term for the process of folding, faulting, shearing, compression, or extension of rocks."

dipping - "Description of a contact, geologic unit or fault surface that is inclined, usually given at an angle measured from the horizontal plane."

dip-slip - The component of the movement or slip that is parallel with the dip of a fault.

displacement - The amount of measurable movement across a fault strand or zone.

distal - Said of a sedimentary deposit of fine clastics formed far from the source area.

Early Pleistocene - This period starts with the initiation of glaciation in the northern hemisphere which occurred at the end of the Pliocene. This is a floating boundary as new data is acquired and is believed to have occurred between 2.0 to 2.2 million years ago. The Early Pleistocene ended at the Brunhes-Matuyama earth magnetic boundary at approximately 670 +/- 10-20 kya.

erosion - Process by which rock and other earth material is broken down and removed.

erosional surface - "A land surface shaped and subdued by the action of erosion, especially by running water. The term is generally applied to a level or nearly level surface."

escarpment - A steep slope or long cliff that occurs from faulting and resulting erosion and separates two relatively level areas of differing elevations. Usually escarpment is used interchangeably with scarp.

expansive clay - Clay that is prone to large volume changes that are directly related to changes in water content.

extension - Process by which one side has moved away from the other side.

fan morphology - the geomorphology (surface form) of a alluvial fan surface.

fan surface - the exposed surface of a fan, but can also refer to buried older fan surfaces preserved in the stratigraphic record by local deposition.

fan-bajada - A bajada consists of a series of coalescing alluvial fans along a mountain front. These fan-shaped deposits form from the deposition of sediment within a stream onto flat land at the base of a mountain.

fan-terrace - "A relict landform consisting of thick gravel, sand, and boulder deposits occurring along mountain fronts. Fan terraces are no longer areas of deposition as active alluvial fans are (due either to tectonic uplift or entrenchment of main washes)."

fat clay - Clay of relatively high plasticity.

fault - "A break in the continuity of a body of rock classified by the type of motion along it: joint, no motion along the fracture; strike-slip, horizontal motion parallel to the fault plane; dip-slip, vertical motion perpendicular to the fault plane."

fault plan - A fault surface that is more or less planar.

fault strand - "A single fault of, or related to a group of faults; usually used to describe one fault within a fault zone."

fault strike - Compass direction aligned with the horizontal orientation of the fault.

fault trenching - See paleoseismic analysis.

Fault Zone - An area where many sub-parallel and interconnecting fault strands occur.

faulting - The structural process whereby deformation occurs along a fault or fault zone.

fining upward sequence - A sequence of sediments which due to changes in the depositional environment become finer as the deposition continues. The younger sediments become progressively finer.

flower structure - "In detail many strike-slip faults at surface consist of en echelon and/or braided segments.. In cross-section the displacements are dominantly reverse or normal in type depending on whether the overall fault geometry is transpressional (i.e. with a small component of shortening) or transtensional (with a small component of extension). As the faults tend to join downwards onto a single strand in basement, the geometry has led to these being termed flower structure"

fold axis - the line at the hinge of a fold.

fold scarp - Where the process of deformation by folding leaves evidence of that folding at the earth's surface.

folding - "A structural process where fold structures are formed by the deformation of geologic units into curved, bent and crumpled shapes."

Geomorphic analysis - "Study of landforms, usually including their description, classification, distribution, genesis and evolution."

geomorphology - "The science that treats the general configuration of the Earth's surface. The study of the classification, description, nature, origin and development of landforms, and the history of geologic changes as recorded by these surface features."

glaciation - "The formation, movement, and recession of glaciers or ice sheets. A collective term for the geological processes of glacial activity and the resulting effects on the earth's surface."

graben - "An elongate, down dropped crustal unit or block that is bounded by faults on it's long sides."

inactive fault - A fault that does not offset Holocene aged sediments.

interglacial - Pertaining to the time between glaciations.

inter-stadial - "A warmer substage of a glacial stage, marked by a temporary retreat of the ice."

Lakewood Formation - In the type localities south of the study area, the Lakewood Formation is a shallow marine dominantly sandy unit. Basal members are estimated to be approximately 330,000 years old (Mueller, 2002). The use of Lakewood Formation in this report was adopted from Parsons (2011) mostly used as a term to define a marker unit; however, age estimates of the local “Lakewood Formation” indicate that this unit is likely older than 600,000 years. Hence, the unit identified as “Lakewood Formation” at the site may not be the same formation as identified as Lakewood Formation in the Los Angeles Basin south of the study area.

Late Pleistocene - The period of time in the Pleistocene Epoch between approximately 125 to 15-18 thousand years ago.

late Quaternary - A part of the geologic time scale representing the latter half of the Quaternary period which is defined from 2.6 million years ago to the present.

Latest Pleistocene - The period of time in the Pleistocene Epoch between approximately 12-15 to 10-11 thousand years ago and represent the end of the last major glaciation in the northern hemisphere.

left step - See step

left-lateral - A strike-slip fault across which a viewer would see the block on the opposite side of the fault move to the left.

Lineament - "A quasi-linear alignment of a color contrast (tonal lineament), vegetation variations (vegetation lineament), or topographic features (geomorphic lineament)."

Marine Deposit - Sediments deposited in a marine environment.

marine isotope stage - "Alternating warm and cool periods in the Earth's paleoclimate, deduced from oxygen isotope data reflecting changes in temperature derived from data from deep sea core samples. The data are derived from pollen and foraminifera (plankton) remains in drilled marine sediment cores, and other data that reflect historic climate."

marker horizon/ marker bed - "A horizon or bed that is used to correlate stratigraphy across several borings, CPTs, or other subsurface data."

Middle Pleistocene - The period of time in the Pleistocene Epoch between approximately 670 to 125 thousand years ago and approximately coincides with marine isotope stage 5e.

Miocene - "An epoch of the early Tertiary period, roughly from 5 to 23 million years ago."

neotectonic - The study of the motions and deformations of the Earth's crust (geological and geomorphological processes) which are current or recent in geologic time. The term may also refer to the motions/deformations in question themselves.

"normal-separation fault, or normal fault" - "A fault, generally, and often steeply, inclined, where the hanging wall block has moved down relative to the foot wall block; usually produced by extension."

Oblique – reverse fault - "A fault that combines some strike-slip motion with some dip-slip motion in which the upper block, above the fault plane, moves up over the lower block."

older alluvium - Pleistocene aged alluvial deposits.

osl - "Optically stimulated luminescence (OSL) is a method for measuring doses from ionizing radiation. The optical dating method relies on the assumption that the mineral grains were sufficiently exposed to sunlight before they were buried. This is usually, but not always, the case with Aeolian deposits, such as sand dunes and loess, and some water-laid deposits.

All sediments and soils contain trace amounts of radioactive isotopes including uranium, thorium, rubidium and potassium. These slowly decay over time and the ionizing radiation they produce is absorbed by other constituents of the soil sediments such as quartz and feldspar. The radiation damage accumulates at a rate over time determined by the amount of radioactive elements in the sample. Exposure to sunlight resets the luminescence signal and so the time period since the soil was buried can be calculated."

oxide - "A mineral compound characterized by the linking of oxygen with one or more metallic elements, such as manganese oxide, MnO, or iron oxide, FeO."

paleo-channel - A remnant of an inactive river or stream channel that has been either filled or buried by younger sediment.

Paleoseismic - "Pertaining to an earthquake or earth vibration that happened decades, centuries, or millennia ago."

paleoseismic fault study - A study of past earthquake surface ruptures whereby a trench is dug across the fault and offset stratigraphy are used to characterize the timing and/or slip in those past events.

paleosol - A buried soil; a soil of the past.

parent sediment - The original sediment deposited.

pedogenic - Pertaining to soil formation.

Peninsular Ranges - "A group of mountain ranges, in the Pacific Coast Ranges, which stretch 1,500 km (930 mi) from southern California in the United States to the southern tip of Mexico's Baja California peninsula; they are part of the North American Coast Ranges that run along the Pacific coast from Alaska to Mexico."

Pleistocene - "The Pleistocene Epoch represents the period of time between 2.0 to 2.6 million to 10,000 to 11,000 years ago. The initiation and cessation of the Pleistocene time boundaries have changed in recent times but is defined the represent the period of northern hemisphere glaciation period."

pluviality - "Pertaining to rain, or to precipitation. Occurring through or formed by the action of rain."

projected fault - The mapped trace of a blind fault that has been extended along the fault plane to the ground surface.

Quaternary period - A unit of the geologic time scale representing the time from 2.6 million years ago to the present.

relict surfaces - Surface that remains after other parts of the surface have disappeared.

restraining bend - "Restraining bends are transpressional structures that form where the orientation of a strike-slip fault becomes oblique to the regional slip vector causing local compression or uplift. They also form where two segments of a strike-slip fault overlap, and the relay zone between the segments experiences transpression. Restraining bends often form positive flower structures or pop-up ridges."

reverse fault - "A dip-slip fault, generally, and often steeply, inclined, where the hanging wall block has moved up (or over) the foot wall block; usually produced by compression."

right-lateral displacement - "Offset where one side is moved to the right, relative to the other side."

right-lateral strike-slip fault - "A strike-slip fault, generally subvertical, where displacement occurs horizontally and parallel to the strike of the fault."

San Pedro Formation -

scarp - is a small step on the ground surface where one side of a fault has moved vertically with respect to another. It is the topographic expression of faulting attributed to the displacement of the land surface by movement along faults.

secondary fault - Smaller faults associated with movement of the main fault.

sediment age data - refers to an estimated numerical age for sediments. The age of sediments can be evaluated by various means. For example OSL, soil pedogenic stratigraphic analysis, Carbon-14 to name a few.

seismic line - The line along which the seismic study is conducted.

seismic reflection/refraction - "A method of exploration geophysics that uses the principles of seismology to estimate the properties of the Earth's subsurface from reflected seismic waves. The method requires a controlled seismic source of energy, such as dynamite/Tovex, a specialized air gun or a seismic vibrator.

sense of offset – Refers to whether a fault exhibits normal, reverse, right- or left-lateral offset across the fault.

shear surface - A polished or striated surface caused by the movement of two surfaces against each other.

soil - The product of weathering and addition of clays and minerals to a sediment deposit developed over time.

soil horizon - "A layer of soil that is distinguishable from adjacent layers by characteristic physical properties such as structure, color, or texture."

soil stratigraphic analysis - The analysis of soil or soils developed in a stratigraphic column to estimate the age of soil development.

sonic core boring - "A sonic drill head works by sending high frequency resonant vibrations down the drill string to the drill bit, while the operator controls these frequencies to suit the specific conditions of the soil/rock geology.

step - i.e. Fault Step: "A jog, skip or disconnection in a fault or other structure towards one side; left step, jog to the left; right step, jog to the right. "

strain partitioning - Where multiple fault systems develop each of which exhibit primarily pure strike-slip and dip-slip motion to accommodate oblique regional tectonic stress. For example, a system of right-lateral faults and normal faults develop in a region to collectively accommodate right-lateral extensional tectonic stress.

stratigraphic analysis - "Study of geologic packages of rocks, usually including their description, classification, genesis and deformation."

stratigraphic trap - A trap for oil or gas that is the result of lithologic changes rather than structural deformation.

stratigraphic units - "Distinct, usually smaller, packages of sediments that have been defined and distinguished from other packages of sediment."

stratigraphically conformable - "Unbroken deposition, no break or hiatus (break or interruption in the continuity of the stratigraphic record)"

stratigraphy - Layers of sediment deposited and accumulated on the earth's surface.

strike - "The direction taken by a structural surface, e.g. a bedding or fault plane, as it intersects the horizontal."

strike-slip fault - A fault with a vertical to sub-vertical fault surface that displays evidence of horizontal and opposite displacement.

structural analysis - "Study of the geologic structures, including stratigraphy and geomorphology, and how they have been deformed through time."

structural complexity - "An area or region where deformation is not accommodated by a simple structure or zone of deformation, but by multiple structures and modes of deformation."

structural feature - "A fault, fold or other geologic feature that accommodates deformation or has been tectonically deformed."

subsidence - The sudden sinking or gradual downward settling of the Earth's surface with little or no horizontal motion.

subsurface - The soil and rock generally located ten's to hundred's of feet beneath the earth's surface.

subsurface mapping - "The identification, definition and correlation of geologic units beneath the earth surface, by using drilling, coring or geophysical methods across an area or region."

Surface Projection - The project of a geologic feature at depth to the earth's surface. Commonly used for fold axis and faults that do not reach the surface (blind).

surficial sediments - Sediments that are near the surface.

syncline - A fold that is concave in the direction of the youngest beds in the folded sequence.

syncline/ synclinal fold - A fold of which the core contains the stratigraphically younger rocks; it is generally concave upward.

synform - a fold whose limbs close downward in strata for which the stratigraphic sequence is unknown.

tectonic - "Refers to the geological unifying theory of Plate Tectonics involving the geologic ramifications of the interaction of tectonic plates (i.e. tectonic stresses, deformation, location of most active volcanoes and fault zones) The movement and deformation of geologic deposits."

tectonic kinematics - Refers to what type of geologic structures such as folds and faults that develop to accommodate tectonic forces in an area.

tectonic stress/ stress regimes - Refers to the forces produced by plate tectonics (motion of the plates interacting with each other). Tectonic strain is the actual deformation by folding and/or faulting that is a direct result from the tectonic stress.

terrestrial deposits - "continental deposit, a sedimentary deposit formed on land without the action of water, e.g. glacial till or sand dunes."

Topanga Formation - A Miocene age marine sedimentary unit throughout the Los Angeles Basin.

topographic feature - "A hill, swale, ridge, fan, escarpment, fault scarp."

topographic lineament - Same as Geomorphic Lineament (see lineament).

transect - Surface location of subsurface evaluation similar to a cross section.

translocated clay - Clays moved into sediments during soil development.

transpression - "When a region of the Earth's crust experiences strike-slip shear and a component of shortening, resulting in oblique shear. Transpression typically occurs at a regional scale along plate boundaries characterized by oblique convergence. More locally, transpression can occur along strike-slip fault zones which are not perfectly planar."

Transverse Ranges - "A group of mountain ranges of southern California, in the Pacific Coast Ranges physiographic region in North America. The Transverse Ranges begin at the southern end of the California Coast Ranges and lie between Santa Barbara and San Diego counties. They derive the name Transverse Ranges due to their east–west orientation, making them transverse to the general north–south orientation of most of California's coastal mountains"

trending - "The general direction of a structure or fault (i.e. fold axis, fault strike)."

type section - The originally described sequence of strata that constitute a stratigraphic unit. It serves as an objective standard with which spatially separated parts of the unit may be compared.

uplift - Rising of the land surface (topography) typically due to tectonic processes (i.e. folding or faulting).

APPENDIX B – ATTACHED PLATES

Plate KGS-FM1	Preliminary Fault Location Zone Map, Century City Area
Plate KGS-T1	Modified CPT and Boring Cross-Section of Transects 1 & 8 of PB (2011), Century City Area, City of Los Angeles
Plate KGS-T2	Modified CPT and Boring Cross-Section of Transects 2 & 2E of PB (2011), Century City Area, City of Los Angeles
Plate KGS-T3	Modified CPT and Boring Cross-Section of Transect 3 of PB (2011), Century City Area, City of Los Angeles
Plate KGS-T4	Modified CPT and Boring Cross-Section of Transect 4 of PB (2011), Century City Area, City of Los Angeles
Plate KGS-T5	Cross-Section from Beverly Hills High School to El Rodeo School utilizing Parsons (2011) and Leighton Consulting Inc. (2012a, 2012b) data among others
Plate KGS-T7	Modified CPT and Boring Cross-Section of Transect 7 of PB (2011), Century City Area, City of Los Angeles

DESCRIPTION OF SYMBOLS

TRANSECTS (CROSS SECTIONS)

TRANSECT 7 — Approximate Transect (cross-section) locations evaluated during this study.

FAULT LOCATIONS

The interpreted fault locations shown were identified along transects from subsurface data (boring, CPT, geophysical, and trenches). The strike and dip direction of the individual faults is unknown, however, general fault zones A, F, G and H are shown to provide what is believed to be reasonable general strike of faulting within these zones.

- Approximate location of interpreted fault that is possibly inactive based on evaluation of subsurface data.
- Approximate location of interpreted fault in which activity is unknown based on evaluation of subsurface data.
- F7-1 ML3-5 H2E-4 F3-3a F3-3b — Interpreted fault strand designation. Fault F7-1 is a fault in Fault Zone F on Transect 7, strand no. 1; fault ML3-5 is primarily based on Mark Legg Geophysical data (Legg, 2012a, 2012b), but may also be supported by other subsurface data as indicated; H2E-4 infers a fault in Fault Zone H along Transect T2, fault strand no. 4; Fault F3-3b is in Fault Zone F, Transect 3, fault strand no. 3 (note, the "a" and "b" indicates that Fault F3-3 merges into a single fault at depth.
- Apparent dip-slip displacement identified.
- Apparent reverse slip displacement identified.

FAULT PROJECTION TO SURFACE

Location shown on the map

Surface of earth

Vertical line projection from the top of the fault to the surface.

Fault at depth

DESIGNATED FAULT ZONES

- Fault Zone A
- Fault Zone F
- Fault Zone G
- Fault Zone H

GENERALIZED BEDDING AND NATURAL CONTOURS

- Generalized strike and dip direction of underlying sedimentary units, typically of Cheviot Hills Deposits (CHD) and/or San Pedro Sequence (SPS) age.
- 295' — Topographic contours from Hoots (1931; 5-foot contours)
- Approximate location of natural drainage prior to urbanization after 1931 based on Hoots (1931).

STRATIGRAPHIC CONTROL AREAS DEPICTING FAULT ACTIVITY

A color scheme is utilized to depict fault activity based on stratigraphic control provided by evaluation of the subsurface data. For example, any section of the transects or trench depicting a yellow, orange, green or blue line (swath) as described below indicates that the subsurface data evaluation revealed sufficient control to suggest that unfaulted sediments occur along this area. See inset Figures A and B for generalized stratigraphy and additional explanation for transect color designations.

Youngest

- Stratigraphic members of the BrCW deposits (lower members) that are latest Pleistocene are interpreted to be continuous and not offset by an underlying fault.
- Stratigraphic members of the BCWD1are interpreted to be continuous and not offset by an underlying fault.
- The BCWD1/BCWD2 contact and/or some stratigraphic members of the BCWD2 are interpreted to be continuous and not offset by an underlying fault.
- The BCWD2/CHD contact and/or some stratigraphic members of the CHD are interpreted to be continuous and not offset by an underlying fault.
- The CHD/SPS contact and/or some stratigraphic members of the SPS are interpreted to be continuous and not offset by an underlying fault.

Oldest

Figure A - Diagramatic cross section of local stratigraphy and structure

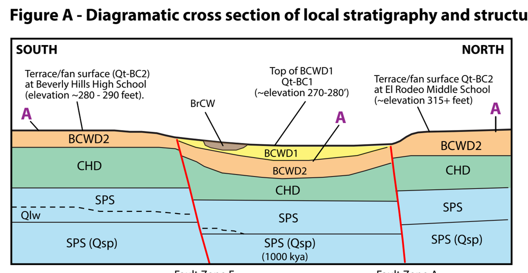
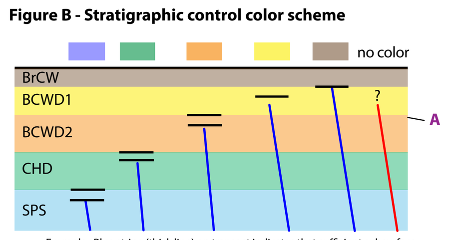


Figure B - Stratigraphic control color scheme



Example: Blue stripe (thick line) on transect indicates that sufficient subsurface data exists to suggest that the CHD/SPS contact, or some members of the upper SPS, or the upper contact of the San Pedro Formation is not offset. Hence, a continuous soil horizon, erosion surface, or geologic contact ( ) overlies the interpreted fault.

STRATIGRAPHIC NOMENCLATURE

BrCW	**Brown Canyon Wash Deposits** Latest Pleistocene to Holocene alluvial deposits. Type section is within Brown Canyon, however, similar age sediments occur associated with numerous drainages in the Cheviot Hills
BCWD1	**Benedict Canyon Wash Deposits** Pleistocene terrestrial alluvial deposits - younger member
BCWD2	**Benedict Canyon Wash Deposits** Pleistocene terrestrial alluvial deposits- older member Uppermost soil marker horizon A (A in Figures A and B above) occurs at the top of the unit.
CHD	**Cheviot Hills Deposits** Pleistocene terrestrial alluvial deposits
SPS	**San Pedro Sequence** Pleistocene terrestrial upper alluvial members overlying marine Lakewood (Qlw) and San Pedro Formations (Qsp)

Note: Refer to text of the report for the estimated ages of the units.

SYMBOL EXPLANATION FOR DATA FROM LCI (2012a) - Beverly Hills High School

- CB-26 — Approximate location of continuous core boring locations CB-22 to CB-26 shown on cross section C-C'
- CB-21 — Approximat location of continuous core boring locations CB-1 to CB-21 shown cross sections A-A' and B-B'
- FT-5 — Approximate location of Fault Trench
- C C' — Geotechnical cross-sections, which include fault trenches
- 75 — Stike and dip of fault identified in Fault Trench FT-5 which was determine to be inactive
- 90 — Stike of vertical fault identified in Fault Trench FT-3 which was determined to be inactive

SYMBOL EXPLANATION FOR DATA FROM LCI (2012b) - El Rodeo School

- CB-6 — Approximate location of continuous core boring locations CB-1 to CB-6 (some utilized in Transect 7)

SYMBOL EXPLANATION FOR DATA FROM TRC (2008) - 9988 Wilshire Blvd.

- MW-9 — Approximate location of hollow stem auger boring locations MW-3, MW-5 and MW-9 (utilized in Transect 7)

SYMBOL EXPLANATION FOR DATA FROM GEOCON (2013a) - 9900 Wilshire Blvd.

- B-5 — Approximate location of hollow stem auger boring locations B-3 and B-5 provided in Geocon (2013) originally conducted by MACTEC 2008 (utilized in Transect 7)

SYMBOL EXPLANATION FOR DATA FROM GEOCON (2013b) - Westfield Property

- TA-B9 — Approximate location of continuous core boring locations TA-B1 toTA-B9 (utilized in Transect 1-8)

SYMBOL EXPLANATION FOR DATA FROM PARSONS (2011)

Fault Investigation:

- Prior Seismic Reflection Line
- P-Wave Seismic Reflection Line
- T8-C15 — CPT Sounding Location
- T8-B5 (80') — Continuous Core Boring Location and Total Depth Drilled

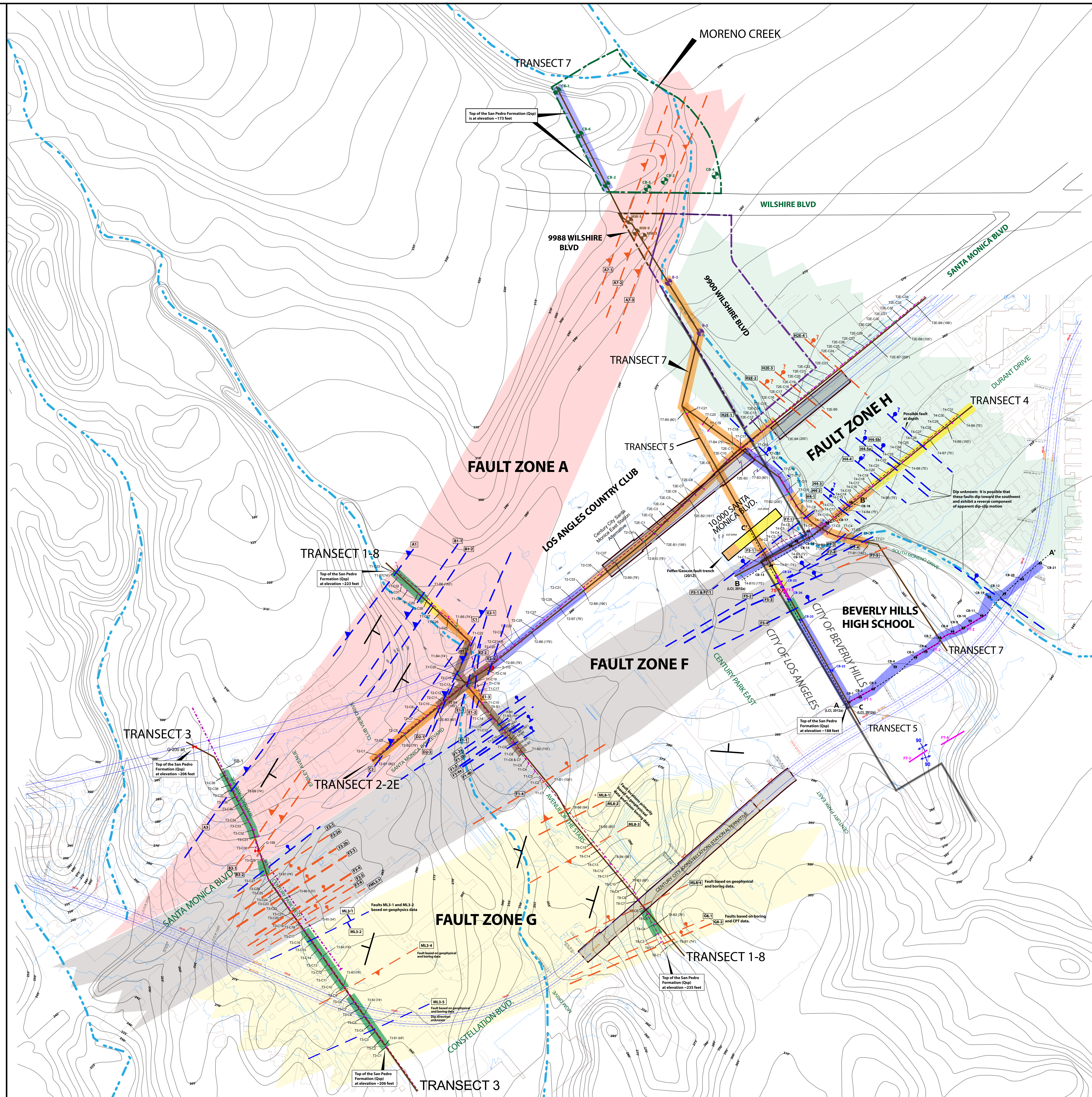
Geotechnical / Soil-Gas Investigation:

- G-206 — Rotary-Wash Boring Location
- S-115 — Sonic core Location
- SB-2 — Prior Sonic Core Location (Mactec, 2010)

Symbols Legend:

- Centerline of Tracks (proposed)
- Cross Passages (Approximate; proposed)

Note: Missing CPT's and Borings on all Transects were not drilled.



N

SCALE: 1" = 100'

Kenney GeoScience	CLIENT: BEVERLY HILLS UNIFIED SCHOOL DISTRICT PROJECT: STRUCTURAL AND STRATIGRAPHIC EVALUATION OF THE CENTURY CITY AREA, CALIFORNIA	**PRELIMINARY FAULT LOCATION ZONE MAP CENTURY CITY AREA** CITY OF LOS ANGELES AND CITY OF BEVERLY HILLS, CALIFORNIA	Job No. 723-11 Date: JULY 8, 2014 Drafted by: MK & DM **PLATE KGS-FM1**

TRANSECT 1

Symbol Descriptions for Borings

- Surface of the Earth
- Geologic contact
- RB — Reddish Brown soil
- Approximate upper limit of a pedogenic parameter (i.e. Bt, Bk, Ca, or oxides)
- Shaded region delineating secondary mineralization (Ca, Mn, or Fe) or pedogenic horizon (B or Bt)
- B or Bt — Argillic pedogenic horizon (Bt horizon)
- Ca or Bk — Carbonate layer - Ca used if uncertain of pedogenic source (i.e. groundwater) and Bk utilized if most likely produced by pedogenic processes
- Mn — Manganese oxide layer
- Fe — Iron oxide layer or just "oxidized" layer
- Approximate elevation of groundwater observed by Parsons (2011)
- No sample recovered from cores as indicated on boring logs
- b: 15-20° — Dip of bedding as indicated on boring logs
- Erosion surface
- Silts and Clays / Sands and Gravels — Fining upward sequence typically exhibiting coarser grained sediments at the base (sands and gravels) and finer grained sediments near the top (silts and clays)
- 30% — In places, the percentage of gravel as indicated on the PB (2011) logs (i.e. 35 to 60%)
- Erosion surface bounding defined geologic members (i.e. Benedict Canyon Wash, Cheviot Hills, and San Pedro Sequence depositional units)

Natural Topography

Approximate location of original natural surface evaluated from five foot contours provided on Hoots, 1931.

Marker Horizons

A through F — Qeb & Qfob — Marker horizons/units A through F. Marker horizon A occurs at the top of the BCWD2 and is estimated to be approximately 200 to 350 kya; marker horizons B, C, and D occur within the CHD; marker horizons E and F and marker units Qeb and Qfob and occur within the upper SPS.

Colors assigned to sediment compositions identified on the boring logs - not all possible combinations are shown.

Color scheme	Grain size	Unified Soil Clasiffication System symbol
	Clay (fat)	(CH)
	Clay (lean)	(CL)
	Clayey Sand	(SC)
	Sandy Silt	(ML)
	Sand	(SP, SW, SM)
	Gravels	(GP, GW, GM, or lesser percentage)

Generalized fining upward sequence

FINING UPWARD SEQUENCE — Soil type Classification — Pedogenic (soil) properties (~ upper 8 to 10 feet of the fining upward sequence)

- Clays and silts — CL/CH — A: Organic rich horizon (typically mechanically eroded away)
- Bt: Argillic horizon (clays)
- Bk or Ca: Carbonate (Ca listed if pedogenic source is unknown) horizon.
- Silts, sands, gravels, with clay — Mn: Manganese & Iron Oxides
- SP/SW
- Gravels — GW
- Erosion surface
- possible remnant paleosol
- Buried fining upward sequence

Faults

B3-1 — F1-3

Approximate interpreted location of fault. Barbs show direction of apparent dip-slip motion (separation). Fault designation shown in box. Faults with in sufficient data to evaluate activity are shown as orange. Faults with sufficient data to suggest that it is inactive are shown in blue based on State of California fault activity guidelines.

GEOLOGIC UNITS

- **Af** — **Artificial Fill**
- **BrCW** — **Brown Canyon Wash deposits (BrCW)** Latest Pleistocene to Holocene; Terrestrial alluvium
- **BCWD** — **Benedict Canyon Wash Deposits** Middle to latest Pleistocene; Terrestrial alluvium; BCWD1 is younger than BCWD2
- **CHD** — **Cheviot Hills Deposits (CHD)** Possibly early to middle Pleistocene; Terrestrial
- **San Pedro Sequence (SPS)** Early Pleistocene; Terrestrial alluvial overlying marine sediments; Includes marker beds E, F, Qfob and Qeb, and marine Lakewood and San Pedro Formations
- **F Qfob** — Marker horizon E, F, Qfob
- **Qeb** — Marker horizons Qeb
- **Qlw** — Lakewood Formation (Qlw) - marine shoreline deposits
- **Qsp** — San Pedro Formation

BORING DATA SOURCES AND SYMBOLOGY

- T4-B1 — Approximate boring location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. Boring numbers start at "1" for each of their transects.
- T4-C1 — Approximate Coned Penatration Test (CPT) location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. CPT numbers start at "1" for each of their transects.
- CPT Data: Sleeve Stress, Tip Stress
- Geotechnical / Soil-Gas Investigation data utilized by Parsons (2011)
  - G-206 — Rotary-Wash Boring Location
  - S-115 — Sonic core Location
  - SB-2 — Prior Sonic Core Location (Mactec, 2010)
- CB-26 / CB-21 — Approximate boring location performed by Leighton Consulting, Inc (LCI, 2012a) at Beverly Hills High School
- CB-6 — Approximate boring location performed by Leighton Consulting, Inc (2012b) at El Rodeo School
- MW-9 — Approximate boring location performed by TRC (2008) at 9988 Wilshire Blvd.
- B-5 — Approximate boring location performed by Geocon (2013a) at 9900 Wilshire Blvd. Borings from MACTEC (2006) as appendix in Geocon (2013a).
- TA-B9 — Approximate boring location performed by Geocon (2013b) for the Westfield Property located along the Avenue of the Stars
- TRC MW-3 — Approximate boring location performed by TRC (2008) for the 9988 Wilshire Blvd. Property

0 10' 20' 40' SCALE (VERTICAL = 2XHORIZONTAL) 0 20' 40' 80'

VERTICAL SCALE: 1" = 20'-0" HORIZONTAL SCALE: 1" = 40'-0"

Modified from Parsons Brinkerhoff report 4951-10-1561 dated 10.14.2011, Plate No. 4 for Transects 1 and 8.

Kenney GeoScience	CLIENT: BEVERLY HILLS UNIFIED SCHOOL DISTRICT PROJECT: STRUCTURAL AND STRATIGRAPHIC EVALUATION OF THE CENTURY CITY AREA, CALIFORNIA	Modified CPT and Boring Cross Section of **Transects 1 & 8** of Parsons Brinkerhoff (2011) **TRANSECT 1 THIS STUDY** Century City Area, City of Los Angeles	Job No. 723-11 Date: JULY 8, 2014 Drafted by: DS, MK **PLATE KGS-T1**

TRANSECT 2

Symbol Descriptions for Borings

- Surface of the Earth
- Geologic contact
- RB — Reddish Brown soil
- Approximate upper limit of a pedogenic parameter (i.e. Bt, Bk, Ca, or oxides)
- Shaded region delineating secondary mineralization (Ca, Mn, or Fe) or pedogenic horizon (B or Bt)
- B or Bt — Argillic pedogenic horizon (Bt horizon)
- Ca or Bk — Carbonate layer - Ca used if uncertain of pedogenic source (i.e. groundwater) and Bk utilized if most likely produced by pedogenic processes
- Mn — Manganese oxide layer
- Fe — Iron oxide layer or just "oxidized" layer
- Approximate elevation of groundwater observed by Parsons (2011)
- No sample recovered from cores as indicated on boring logs
- b: 15-20° — Dip of bedding as indicated on boring logs
- Erosion surface
- Silts and Clays / Sands and Gravels — Fining upward sequence typically exhibiting coarser grained sediments at the base (sands and gravels) and finer grained sediments near the top (silts and clays)
- 30% — In places, the percentage of gravel as indicated on the PB (2011) logs (i.e. 35 to 60%)
- Erosion surface bounding defined geologic members (i.e. Benedict Canyon Wash, Cheviot Hills, and San Pedro Sequence depositional units)

Natural Topography

Approximate location of original natural surface evaluated from five foot contours provided on Hoots, 1931.

Marker Horizons

A through F; Qeb & Qfob — Marker horizons/units A through F. Marker horizon A occurs at the top of the BCWD2 and is estimated to be approximately 200 to 350 kya; marker horizons B, C, and D occur within the CHD; marker horizons E and F and marker units Qeb and Qfob and occur within the upper SPS.

Colors assigned to sediment compositions identified on the boring logs - not all possible combinations are shown.

Color scheme	Grain size	Unified Soil Classiffication System symbol
	Clay (fat)	(CH)
	Clay (lean)	(CL)
	Clayey Sand	(SC)
	Sandy Silt	(ML)
	Sand	(SP, SW, SM)
	Gravels	(GP, GW, GM, or lesser percentage)

Generalized fining upward sequence

FINING UPWARD SEQUENCE

Soil type Classification

Pedogenic (soil) properties (~ upper 8 to 10 feet of the fining upward sequence)

- Clays and silts — CL/CH
- Silts, sands, gravels, with clay
- Gravels — SP/SW, GW
- A — Organic rich horizon (typically mechanically eroded away)
- Bt — Argillic horizon (clays)
- Bk or Ca — Carbonate (Ca listed if pedogenic source is unknown) horizon.
- Mn — Manganese & Iron Oxides

Erosion surface

possible remnant paleosol

Buried fining upward sequence

Faults

B3-1 F1-3

Approximate interpreted location of fault. Barbs show direction of apparent dip-slip motion (separation). Fault designation shown in box. Faults with in sufficient data to evaluate activity are shown as orange. Faults with sufficient data to suggest that it is inactive are shown in blue based on State of California fault activity guidelines.

GEOLOGIC UNITS

- **Af** — **Artificial Fill**
- **BrCW** — **Brown Canyon Wash deposits (BrCW)** Latest Pleistocene to Holocene; Terrestrial alluvium
- **BCWD** — **Benedict Canyon Wash Deposits** Middle to latest Pleistocene; Terrestrial alluvium; BCWD1 is younger than BCWD2
- **CHD** — **Cheviot Hills Deposits (CHD)** Possibly early to middle Pleistocene; Terrestrial

San Pedro Sequence (SPS)
Early Pleistocene
Terrestrial alluvial overlying marine sediments
Includes marker beds E, F, Qfob and Qeb, and marine Lakewood and San Pedro Formations

- F Qfob — Marker horizon E, F, Qfob
- Qeb — Marker horizons Qeb
- Qlw — Lakewood Formation (Qlw) - marine shoreline deposits
- Qsp — San Pedro Formation

BORING DATA SOURCES AND SYMBOLOGY

- T4-B1 — Approximate boring location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. Boring numbers start at "1" for each of their transects.
- T4-C1 — Approximate Coned Penatration Test (CPT) location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. CPT numbers start at "1" for each of their transects.

CPT Data
Sleeve Stress Tip Stress

Geotechnical / Soil-Gas Investigation data utilized by Parsons (2011)

- G-206 — Rotary-Wash Boring Location
- S-115 — Sonic core Location
- SB-2 — Prior Sonic Core Location (Mactec, 2010)

- CB-26, CB-21 — Approximate boring location performed by Leighton Consulting, Inc (LCI, 2012a) at Beverly Hills High School
- CB-6 — Approximate boring location performed by Leighton Consulting, Inc (2012b) at El Rodeo School
- MW-9 — Approximate boring location performed by TRC (2008) at 9988 Wilshire Blvd.
- B-5 — Approximate boring location performed by Geocon (2013a) at 9900 Wilshire Blvd. Borings from MACTEC (2006) as appendix in Geocon (2013a).
- TA-B9 — Approximate boring location performed by Geocon (2013b) for the Westfield Property located along the Avenue of the Stars
- TRC MW-3 — Approximate boring location performed by TRC (2008) for the 9988 Wilshire Blvd. Property

0 10' 20' 40'
VERTICAL SCALE: 1" = 20'-0"

SCALE (VERTICAL = 2XHORIZONTAL)

0 20' 40' 80'
HORIZONTAL SCALE: 1" = 40'-0"

Modified from Parsons Brinkerhoff report 4951-10-1561 dated 10.14.2011, Plate No. 5 for Transects 2 & 2E.

Kenney GeoScience

CLIENT: BEVERLY HILLS UNIFIED SCHOOL DISTRICT

PROJECT: STRUCTURAL AND STRATIGRAPHIC EVALUATION OF THE CENTURY CITY AREA, CALIFORNIA

Modified CPT and Boring Cross Section of **Transects 2 & 2E** of Parsons Brinkerhoff (2011), **TRANSECT T2 THIS STUDY** Century City Area, City of Los Angeles and City of Beverly Hills

Job No. 723-11
Date: JULY 8, 2014
Drafted by: DS, MK

PLATE KGS-T2

TRANSECT 3

Symbol Descriptions for Borings

- Surface of the Earth
- Geologic contact
- RB — Reddish Brown soil
- Approximate upper limit of a pedogenic parameter (i.e. Bt, Bk, Ca, or oxides)
- Shaded region delineating secondary mineralization (Ca, Mn, or Fe) or pedogenic horizon (B or Bt)
- B or Bt — Argillic pedogenic horizon (Bt horizon)
- Ca or Bk — Carbonate layer - Ca used if uncertain of pedogenic source (i.e. groundwater) and Bk utilized if most likely produced by pedogenic processes
- Mn — Manganese oxide layer
- Fe — Iron oxide layer or just "oxidized" layer
- Approximate elevation of groundwater observed by Parsons (2011)
- No sample recovered from cores as indicated on boring logs
- b: 15-20° — Dip of bedding as indicated on boring logs
- Erosion surface
- Silts and Clays / Sands and Gravels — Fining upward sequence typically exhibiting coarser grained sediments at the base (sands and gravels) and finer grained sediments near the top (silts and clays)
- 30% — In places, the percentage of gravel as indicated on the PB (2011) logs (i.e. 35 to 60%)
- Erosion surface bounding defined geologic members (i.e. Benedict Canyon Wash, Cheviot Hills, and San Pedro Sequence depositional units)

Natural Topography

Approximate location of original natural surface evaluated from five foot contours provided on Hoots, 1931.

Marker Horizons

A through F; Qeb & Qfob — Marker horizons/units A through F. Marker horizon A occurs at the top of the BCWD2 and is estimated to be approximately 200 to 350 kya; marker horizons B, C, and D occur within the CHD; marker horizons E and F and marker units Qeb and Qfob and occur within the upper SPS.

Colors assigned to sediment compositions identified on the boring logs - not all possible combinations are shown.

Color scheme / Grain size	Unified Soil Classiffication System symbol
Clay (fat)	(CH)
Clay (lean)	(CL)
Clayey Sand	(SC)
Sandy Silt	(ML)
Sand	(SP, SW, SM)
Gravels	(GP, GW, GM, or lesser percentage)

Generalized fining upward sequence

FINING UPWARD SEQUENCE

Soil type Classification

Pedogenic (soil) properties (~ upper 8 to 10 feet of the fining upward sequence)

	Soil type Classification		
Clays and silts	CL/ CH	A	Organic rich horizon (typically mechanically eroded away)
		Bt	Argillic horizon (clays)
		Bk or Ca	Carbonate (Ca listed if pedogenic source is unknown) horizon.
Silts, sands, gravels, with clay		Mn	Manganese & Iron Oxides
	SP/ SW		
Gravels	GW		Erosion surface

possible remnant paleosol

Buried fining upward sequence

Faults

B3-1 F1-3

GEOLOGIC UNITS

Af	**Artificial Fill**
BrCW	**Brown Canyon Wash deposits (BrCW)** Latest Pleistocene to Holocene; Terrestrial alluvium
BCWD	**Benedict Canyon Wash Deposits** Middle to latest Pleistocene Terrestrial alluvium BCWD1 is younger than BCWD2
CHD	**Cheviot Hills Deposits (CHD)** Possibly early to middle Pleistocene Terrestrial

San Pedro Sequence (SPS)
Early Pleistocene
Terrestrial alluvial overlying marine sediments
Includes marker beds E, F, Qfob and Qeb, and marine Lakewood and San Pedro Formations

F Qfob	Marker horizon E, F, Qfob
Qeb	Marker horizons Qeb
Qlw	Lakewood Formation (Qlw) - marine shoreline deposits
Qsp	San Pedro Formation

BORING DATA SOURCES AND SYMBOLOGY

T4-B1	Approximate boring location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. Boring numbers start at "1" for each of their transects.
T4-C1	Approximate Coned Penatration Test (CPT) location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. CPT numbers start at "1" for each of their transects.

CPT Data
Sleeve Stress Tip Stress

Geotechnical / Soil-Gas Investigation data utilized by Parsons (2011)

G-206	Rotary-Wash Boring Location
S-115	Sonic core Location
SB-2	Prior Sonic Core Location (Mactec, 2010)

CB-26 CB-21	Approximate boring location performed by Leighton Consulting, Inc (LCI, 2012a) at Beverly Hills High School
CB-6	Approximate boring location performed by Leighton Consulting, Inc (2012b) at El Rodeo School
MW-9	Approximate boring location performed by TRC (2008) at 9988 Wilshire Blvd.
B-5	Approximate boring location performed by Geocon (2013a) at 9900 Wilshire Blvd. Borings from MACTEC (2006) as appendix in Geocon (2013a).
TA-B9	Approximate boring location performed by Geocon (2013b) for the Westfield Property located along the Avenue of the Stars
TRC MW-3	Approximate boring location performed by TRC (2008) for the 9988 Wilshire Blvd. Property

VERTICAL SCALE: 1" = 20'-0" (0, 10', 20', 40')

SCALE (VERTICAL = 2XHORIZONTAL)

HORIZONTAL SCALE: 1" = 40'-0" (0, 20', 40', 80')

Modified from Parsons Brinkerhoff report 4951-10-1561 dated 10.14.2011, Plate No. 6 for Transect 3.

Kenney GeoScience

CLIENT:
BEVERLY HILLS UNIFIED SCHOOL DISTRICT

PROJECT:
STRUCTURAL AND STRATIGRAPHIC EVALUATION OF THE CENTURY CITY AREA, CALIFORNIA

Modified CPT and Boring Cross Section of
Transect 3
of Parsons Brinkerhoff (2011),
Century City Area, City of Los Angeles

Job No. 723-11
Date: JULY 8, 2014
Drafted by: DS, MK

PLATE KGS-T3

Symbol Descriptions for Borings

- Surface of the Earth
- Geologic contact
- RB — Reddish Brown soil
- Approximate upper limit of a pedogenic parameter (i.e. Bt, Bk, Ca, or oxides)
- Shaded region delineating secondary mineralization (Ca, Mn, or Fe) or pedogenic horizon (B or Bt)
- B or Bt — Argillic pedogenic horizon (Bt horizon)
- Ca or Bk — Carbonate layer - Ca used if uncertain of pedogenic source (i.e. groundwater) and Bk utilized if most likely produced by pedogenic processes
- Mn — Manganese oxide layer
- Fe — Iron oxide layer or just "oxidized" layer
- Approximate elevation of groundwater observed by Parsons (2011)
- No sample recovered from cores as indicated on boring logs
- b: 15-20° — Dip of bedding as indicated on boring logs
- Erosion surface
- Silts and Clays / Sands and Gravels — Fining upward sequence typically exhibiting coarser grained sediments at the base (sands and gravels) and finer grained sediments near the top (silts and clays)
- 30% — In places, the percentage of gravel as indicated on the PB (2011) logs (i.e. 35 to 60%)
- Erosion surface bounding defined geologic members (i.e. Benedict Canyon Wash, Cheviot Hills, and San Pedro Sequence depositional units)

Natural Topography

Approximate location of original natural surface evaluated from five foot contours provided on Hoots, 1931.

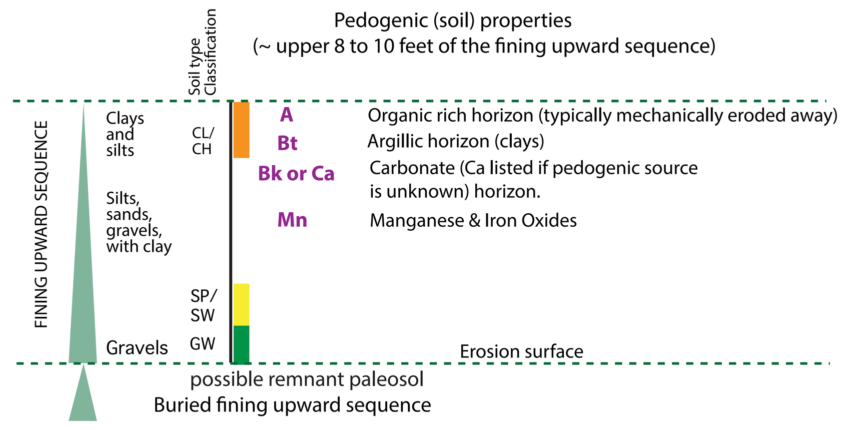
Marker Horizons

A through F, Qeb & Qfob — Marker horizons/units A through F. Marker horizon A occurs at the top of the BCWD2 and is estimated to be approximately 200 to 350 kya; marker horizons B, C, and D occur within the CHD; marker horizons E and F and marker units Qeb and Qfob and occur within the upper SPS.

Colors assigned to sediment compositions identified on the boring logs - not all possible combinations are shown.

Color scheme	Grain size	Unified Soil Classification System symbol
	Clay (fat)	(CH)
	Clay (lean)	(CL)
	Clayey Sand	(SC)
	Sandy Silt	(ML)
	Sand	(SP, SW, SM)
	Gravels	(GP, GW, GM, or lesser percentage)

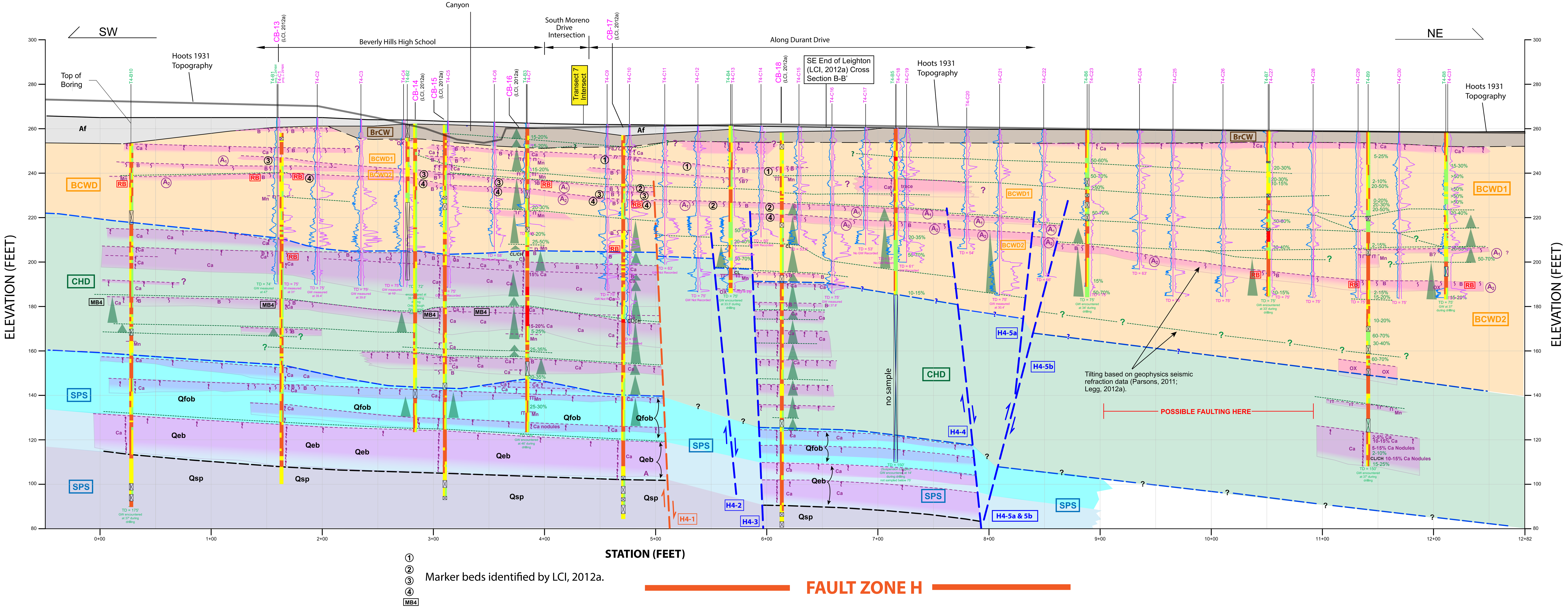
Generalized fining upward sequence



Faults

B3-1 / F1-3 — Approximate interpreted location of fault. Barbs show direction of apparent dip-slip motion (separation). Fault designation shown in box. Faults with in sufficient data to evaluate activity are shown as orange. Faults with sufficient data to suggest that it is inactive are shown in blue based on State of California fault activity guidelines.

TRANSECT 4



GEOLOGIC UNITS

- **Af** — **Artificial Fill**
- **BrCW** — **Brown Canyon Wash deposits (BrCW)** Latest Pleistocene to Holocene; Terrestrial alluvium
- **BCWD** — **Benedict Canyon Wash Deposits** Middle to latest Pleistocene Terrestrial alluvium BCWD1 is younger than BCWD2
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San Pedro Sequence (SPS)
Early Pleistocene
Terrestrial alluvial overlying marine sediments
Includes marker beds E, F, Qfob and Qeb, and marine Lakewood and San Pedro Formations

- **F Qfob** — Marker horizon E, F, Qfob
- **Qeb** — Marker horizons Qeb
- **Qlw** — Lakewood Formation (Qlw) - marine shoreline deposits
- **Qsp** — San Pedro Formation

BORING DATA SOURCES AND SYMBOLOGY

- T4-B1 — Approximate boring location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. Boring numbers start at "1" for each of their transects.
- T4-C1 — Approximate Coned Penatration Test (CPT) location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. CPT numbers start at "1" for each of their transects.
  CPT Data
  Sleeve Stress Tip Stress
- Geotechnical / Soil-Gas Investigation data utilized by Parsons (2011)
  - G-206 Rotary-Wash Boring Location
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- B-5 — Approximate boring location performed by Geocon (2013a) at 9900 Wilshire Blvd. Borings from MACTEC (2006) as appendix in Geocon (2013a).
- TA-B9 — Approximate boring location performed by Geocon (2013b) for the Westfield Property located along the Avenue of the Stars
- TRC MW-3 — Approximate boring location performed by TRC (2008) for the 9988 Wilshire Blvd. Property

0 10' 20' 40'
VERTICAL SCALE: 1" = 20'-0"

SCALE (VERTICAL = 2XHORIZONTAL)

0 20' 40' 80'
HORIZONTAL SCALE: 1" = 40'-0"

Modified from Parsons report 4951-10-1561 dated 10.14.2011, Plate No. 7 for Transect 4.

Kenney GeoScience	CLIENT: BEVERLY HILLS UNIFIED SCHOOL DISTRICT PROJECT: STRUCTURAL AND STRATIGRAPHIC EVALUATION OF THE CENTURY CITY AREA, CALIFORNIA	Modified CPT and Boring Cross Section of **Transect 4** of Parsons Brinkerhoff (2011), Century City Area, City of Los Angeles and City of Beverly Hills	Job No. 723-11 Date: JULY 8, 2014 Drafted by: DS, MK **PLATE KGS-T4**

TRANSECT 5

Symbol Descriptions for Borings

- Surface of the Earth
- Geologic contact
- RB — Reddish Brown soil
- Approximate upper limit of a pedogenic parameter (i.e. Bt, Bk, Ca, or oxides)
- Shaded region delineating secondary mineralization (Ca, Mn, or Fe) or pedogenic horizon (B or Bt)
- B or Bt — Argillic pedogenic horizon (Bt horizon)
- Ca or Bk — Carbonate layer - Ca used if uncertain of pedogenic source (i.e. groundwater) and Bk utilized if most likely produced by pedogenic processes
- Mn — Manganese oxide layer
- Fe — Iron oxide layer or just "oxidized" layer
- Approximate elevation of groundwater observed by Parsons (2011)
- No sample recovered from cores as indicated on boring logs
- b: 15-20° — Dip of bedding as indicated on boring logs
- Erosion surface
- Silts and Clays / Sands and Gravels — Fining upward sequence typically exhibiting coarser grained sediments at the base (sands and gravels) and finer grained sediments near the top (silts and clays)
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Natural Topography

Approximate location of original natural surface evaluated from five foot contours provided on Hoots, 1931.

Marker Horizons

A through F; Qeb & Qfob — Marker horizons/units A through F. Marker horizon A occurs at the top of the BCWD2 and is estimated to be approximately 200 to 350 kya; marker horizons B, C, and D occur within the CHD; marker horizons E and F and marker units Qeb and Qfob and occur within the upper SPS.

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Color scheme / Grain size	Unified Soil Clasiffication System symbol
Clay (fat)	(CH)
Clay (lean)	(CL)
Clayey Sand	(SC)
Sandy Silt	(ML)
Sand	(SP, SW, SM)
Gravels	(GP, GW, GM, or lesser percentage)

Generalized fining upward sequence

Pedogenic (soil) properties
(~ upper 8 to 10 feet of the fining upward sequence)

FINING UPWARD SEQUENCE — Soil type Classification

Clays and silts	CL/ CH	A	Organic rich horizon (typically mechanically eroded away)
		Bt	Argillic horizon (clays)
Silts, sands, gravels, with clay		Bk or Ca	Carbonate (Ca listed if pedogenic source is unknown) horizon.
		Mn	Manganese & Iron Oxides
	SP/ SW		
Gravels	GW		Erosion surface

possible remnant paleosol
Buried fining upward sequence

Faults

B3-1
F1-3

Approximate interpreted location of fault. Barbs show direction of apparent dip-slip motion (separation). Fault designation shown in box. Faults with in sufficient data to evaluate activity are shown as orange. Faults with sufficient data to suggest that it is inactive are shown in blue based on State of California fault activity guidelines.

GEOLOGIC UNITS

- **Af** — **Artificial Fill**
- **BrCW** — **Brown Canyon Wash deposits (BrCW)** Latest Pleistocene to Holocene; Terrestrial alluvium
- **BCWD** — **Benedict Canyon Wash Deposits** Middle to latest Pleistocene; Terrestrial alluvium; BCWD1 is younger than BCWD2
- **CHD** — **Cheviot Hills Deposits (CHD)** Possibly early to middle Pleistocene; Terrestrial

San Pedro Sequence (SPS)
Early Pleistocene
Terrestrial alluvial overlying marine sediments
Includes marker beds E, F, Qfob and Qeb, and marine Lakewood and San Pedro Formations

- F Qfob — Marker horizon E, F, Qfob
- Qeb — Marker horizons Qeb
- Qlw — Lakewood Formation (Qlw) - marine shoreline deposits
- Qsp — San Pedro Formation

BORING DATA SOURCES AND SYMBOLOGY

- T4-B1 — Approximate boring location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. Boring numbers start at "1" for each of their transects.
- T4-C1 — Approximate Coned Penatration Test (CPT) location performed by Parsons Brinkeroff (PB, 2011). "T4" represents the PB transect boring is located on. CPT numbers start at "1" for each of their transects.

CPT Data
Sleeve Stress Tip Stress

Geotechnical / Soil-Gas Investigation data utilized by Parsons (2011)

- G-206 Rotary-Wash Boring Location
- S-115 Sonic core Location
- SB-2 Prior Sonic Core Location (Mactec, 2010)

- CB-26 / CB-21 — Approximate boring location performed by Leighton Consulting, Inc (LCI, 2012a) at Beverly Hills High School
- CB-6 — Approximate boring location performed by Leighton Consulting, Inc (2012b) at El Rodeo School
- MW-9 — Approximate boring location performed by TRC (2008) at 9988 Wilshire Blvd.
- B-5 — Approximate boring location performed by Geocon (2013a) at 9900 Wilshire Blvd. Borings from MACTEC (2006) as appendix in Geocon (2013a).
- TA-B9 — Approximate boring location performed by Geocon (2013b) for the Westfield Property located along the Avenue of the Stars
- TRC MW-3 — Approximate boring location performed by TRC (2008) for the 9988 Wilshire Blvd. Property

0 10' 20' 40'
VERTICAL SCALE: 1" = 20'-0"

SCALE (VERTICAL = 2XHORIZONTAL)

0 20' 40' 80'
HORIZONTAL SCALE: 1" = 40'-0"

Kenney GeoScience

CLIENT: BEVERLY HILLS UNIFIED SCHOOL DISTRICT
PROJECT: STRUCTURAL AND STRATIGRAPHIC EVALUATION OF THE CENTURY CITY AREA, CALIFORNIA

Transect 5
Century City Area, City of Los Angeles and City of Beverly Hills

Job No. 723-11
Date: JULY 8, 2014
Drafted by: MK
PLATE KGS-T5

Faults H2E-1, H2E-2 and H2E-3 are projected from Transect 2E; however there is insufficient data to evaluate whether or not these faults occur in the region of Transect 7. However, data on Transect 7 suggests that if these faults occur here that they are not active.

SCALE (VERTICAL = 2XHORIZONTAL)

VERTICAL SCALE: 1" = 20'-0"

HORIZONTAL SCALE: 1" = 40'-0"

Modified from ParsonsBrinkerhoff report 4951-10-1561 dated 10.14.2011, Plate No. 8 for Transect 7.

Symbol Descriptions for Borings

- Surface of the Earth
- Geologic contact
- RB — Reddish Brown soil
- Approximate upper limit of a pedogenic parameter (i.e. Bt, Bk, Ca, or oxides)
- Shaded region delineating secondary mineralization (Ca, Mn, or Fe) or pedogenic horizon (B or Bt)
- B or Bt — Argillic pedogenic horizon (Bt horizon)
- Ca or Bk — Carbonate layer - Ca used if uncertain of pedogenic source (i.e. groundwater) and Bk utilized if most likely produced by pedogenic processes
- Mn — Manganese oxide layer
- Fe — Iron oxide layer or just "oxidized" layer
- Approximate elevation of groundwater observed by Parsons (2011)
- No sample recovered from cores as indicated on boring logs
- b: 15-20° — Dip of bedding as indicated on boring logs
- Erosion surface
- Silts and Clays / Sands and Gravels — Fining upward sequence typically exhibiting coarser grained sediments at the base (sands and gravels) and finer grained sediments near the top (silts and clays)
- 30% — In places, the percentage of gravel as indicated on the PB (2011) logs (i.e. 35 to 60%)
- Erosion surface bounding defined geologic members (i.e. Benedict Canyon Wash, Cheviot Hills, and San Pedro Sequence depositional units)

Natural Topography

Approximate location of original natural surface evaluated from five foot contours provided on Hoots, 1931.

Marker Horizons

A through F; Qeb & Qfob — Marker horizons/units A through F. Marker horizon A occurs at the top of the BCWD2 and is estimated to be approximately 200 to 350 kya; marker horizons B, C, and D occur within the CHD; marker horizons E and F and marker units Qeb and Qfob and occur within the upper SPS.

Colors assigned to sediment compositions identified on the boring logs - not all possible combinations are shown.

Color scheme	Grain size	Unified Soil Classiffication System symbol
	Clay (fat)	(CH)
	Clay (lean)	(CL)
	Clayey Sand	(SC)
	Sandy Silt	(ML)
	Sand	(SP, SW, SM)
	Gravels	(GP, GW, GM, or lesser percentage)

Generalized fining upward sequence

FINING UPWARD SEQUENCE — Soil type Classification — Pedogenic (soil) properties (~ upper 8 to 10 feet of the fining upward sequence)

- Clays and silts — CL/CH — A: Organic rich horizon (typically mechanically eroded away)
- Bt: Argillic horizon (clays)
- Bk or Ca: Carbonate (Ca listed if pedogenic source is unknown) horizon.
- Silts, sands, gravels, with clay — Mn: Manganese & Iron Oxides
- SP/SW
- Gravels — GW
- Erosion surface
- possible remnant paleosol
- Buried fining upward sequence

Faults

B3-1 F1-3

Approximate interpreted location of fault. Barbs show direction of apparent dip-slip motion (separation). Fault designation shown in box. Faults with in sufficient data to evaluate activity are shown as orange. Faults with sufficient data to suggest that it is inactive are shown in blue based on State of California fault activity guidelines.

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- CPT Data: Sleeve Stress, Tip Stress
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Kenney GeoScience

CLIENT: BEVERLY HILLS UNIFIED SCHOOL DISTRICT

PROJECT: STRUCTURAL AND STRATIGRAPHIC EVALUATION OF THE CENTURY CITY AREA, CALIFORNIA

Modified CPT and Boring Cross Section of **Transect 7** of Parsons Brinkerhoff (2011), with extension to El Rodeo School, Century City Area, City of Los Angeles and City of Beverly Hills

Job No. 723-11

Date: JULY 8, 2014

Drafted by: MK

PLATE KGS-T7

APPENDIX C – ATTACHED REPORTS

1. Earth Consultants International, 2012, Soil-stratigraphic studies for Beverly Hills High School, 241 Moreno Drive, Beverly Hills, California; report prepared for Hill Farrer & Burrill, LLP, report dated April 10, 2012.

2. Earth Consultants International, 2012, Supplemental report on the age of the sediments underlying the Beverly Hills Hih School and vicinity using soil-stratigraphic techniques, 241 Moreno Drive, Beverly Hills, California; report prepared for HIl Farrer & Burrill, LLP, report dated December 21, 2012.

3. Helms, J. (High Desert Consulting, Inc.), 2012, Soil stratigraphy and relative age determinations for a fault rupture hazard assessment, 10,000 Santa Monica Boulevard, Los Angeles, California; report prepared for Geocon, Inc., report dated August 17, 2012.

4. Helms, J. (High Desert Consulting, Inc.), 2013, Soil stratigraphy and relative age estimates for a fault rupture hazard investigation at Westfield Century City Mall, 1801 Avenue of the Stars, 10250 Santa Monica Boulevard, and 1930 Century Park West, Century City – Los Angeles, California; report prepared for Geocon, Inc., report dated July 26, 2013.

5. Soil Tectonics, 2012a, Late Pleistocene Soil Development on Isolated Terraces at Beverly Hills, California; report prepared for Leighton Consulting, Inc., and Kenney GeoScience, report dated May 12, 2012.

6. Soils Tectonics, 2012b, Pedochronological Report for Beverly Hills High School, Beverly Hills, California, report prepared for Leighton Consulting, Inc., report dated May 12, 2012.

7. Legg Geophysical Inc., 2012a; Beverly Hills High School, Active Fault Investigation; report prepared for Beverly Hills High School, report dated January 27, 2012.

8. Legg Geophysical Inc., 2012b, Beverly Hills High School, Independent Review of Metro Century City Area Fault Investigation Report Appendix D (*from Parsons 2011*), report prepared for Beverly Hills High School, report dated May 10, 2012

Earth Consultants International

April 10, 2012
ECI Project No. 3205.02

To: **Hill Farrer & Burrill, LLP**
300 South Grand Avenue, 37th Floor
Los Angeles, California 90071-3147

Attention: **Mr. Kevin Brogan, Partner**

Subject: **Soil-Stratigraphic Studies for Beverly Hills High School, 241 Moreno Drive, Beverly Hills, California**

Dear Mr. Brogan,

Earth Consultants International (ECI) was retained by your firm to conduct a third-party review of the geological work conducted by the Leighton Consulting Group at and in the vicinity of the Beverly Hills High School. Part of the work performed included the review of the soils exposed in the trenches and one of the borings emplaced at the high school for the purpose of estimating the age of the sediments that underlie the site. Understanding the regional depositional history of the geologic materials is critical in developing an appropriate interpretation of the tectonic framework for the area, including the nature and recency of activity of faults and folds that have been either observed or inferred from the subsurface work done to date. This letter report summarizes our work estimating the age of the deposits exposed in two trenches and one boring.

Our analysis of the soils reviewed indicates that most of the high-school site sits on an older, geomorphically stable alluvial fan surface. The near-surface soil that has developed on these older alluvial fan deposits has characteristics that indicate that it has been exposed to soil forming processes for a minimum of about 70,000 years, and probably more than 100,000 years. Given that the upper portion of this soil has been removed and that the top section is now undergoing leaching of its clay fraction, these age estimates are considered minimum values.

This near-surface soil is underlain by a sequence of soils developed in alluvial fan and fluvial sediments that overlie marine sands assigned to the San Pedro Formation. Eight buried soils were described in boring CB-3, indicating that there were several periods of soil formation in between periods of alluvial deposition (and probably erosion). By adding the ages of all of the soils described in the boring, we can estimate the minimum age of the entire alluvial sequence, and thus the absolute minimum age of the San Pedro Formation in this area. The soil age estimates indicate that the alluvial sequence is at a minimum between about 530,000 and 1.3 million years old, depending on the soil age regression curves used. We prefer the first age estimate of 530,000 years, recognizing that this estimate represents only the length of time it took for the various soils to form, and does not account for the length of time it took for the alluvial sediments to be deposited. Other soil-stratigraphic studies to the east of Beverly Hills High School, in the West Hollywood area at the base of the Hollywood Hills, have yielded similar ages of between about 400,000 and 900,000 years for the buried soils – alluvial fan sequence that overlies a marine abrasion platform observed in several borings.

The eastern portion of the campus, below the main escarpment just west of Moreno Drive, is underlain by younger alluvial sediments deposited in the channel of Benedict Canyon Creek (also referred to locally as Moreno Creek), a drainage that incised into the older deposits described above. Three soils developed in younger alluvial deposits were observed and described at the east end of trench T-2. The first (youngest) of these soils has an estimated age of between about 9,500 and 12,500 years. The second soil exposed in the trench is estimated to have been exposed at the surface for about 11,000 years, and the third soil is estimated to have been exposed to soil-forming processes for between about 16,000 and 28,000 years prior to burial. Combining the age of all three soils yields a minimum age for the alluvial sediments exposed in this trench of between about 36,500 and 51,500 years.

Thank you for the opportunity to assist the Beverly Hills School District and your firm with this study. Should you have any questions regarding our attached report, please do not hesitate to contact the undersigned.

Respectfully submitted for
Earth Consultants International, Inc.

Tania Gonzalez, CEG 1859
Vice-President

Soil-Stratigraphic Studies for Beverly Hills High School

BACKGROUND

The term soil as used herein refers to a natural body consisting of layers (or horizons) of mineral and/or organic material that are different from the underlying geologic material in their "morphological, physical, chemical and mineralogical properties and their biological characteristics" (Birkeland, 1984). These differences are the result of weathering and the effects of five main soil-forming factors: parent material, climate, slope or topography, organisms, and time (Jenny, 1941). Time is an important factor because the longer a geologic deposit is exposed to the effects of weathering and soil formation, the better developed the soil characteristics become. We take advantage of this factor when using soils to estimate the age of the deposits.

Soil development occurs on stable geomorphic surfaces (a stable surface is one that is not being impacted by deposition or erosion). Soil development typically starts to occur as soon as a surface stops being eroded or deposited on. In some environments, such as an alluvial plain or alluvial fan, it is not uncommon to find several weakly to moderately well developed buried soils that rest one upon the other, sometimes separated by unaltered sediments (the parent material). The soils represent periods of sub-aerial weathering and soil formation that occurred in between periods of alluvial erosion and deposition. In these environments, the age of the underlying primary deposits is best estimated by summing the age of the individual overlying buried soils. Soil age estimates provide a minimum age for the deposits that the soils formed into, especially in depositional environments where short periods of soil formation occur in between erosional and depositional events.

Furthermore, portions of soil horizons and sometimes even entire soil horizons may be removed (truncated) from the area by erosion during floods or mudflow scour, further limiting the reliability of soils as indicators of the age of the geological deposits that the soils formed into. Nevertheless, if these limitations are recognized and taken into account, soils developed in active fluvial or alluvial fan environments can provide useful information. In areas where suitable datable materials, such as charcoal, are not available, or where the age of the sediments extends beyond the useful range of radiocarbon dating, soil-age estimations are particularly useful.

SCOPE OF WORK and METHODOLOGY

For the Beverly Hills High School project, we were tasked with estimating the age of three near-surface soil profiles exposed in two of the trenches excavated by the Leighton Consulting Group. We were also retained to describe a sequence of soils observed in the core from geotechnical boring CB-3 that exposed, at depth, marine sediments assigned to the San Pedro Formation. By estimating the cumulative age of the soils developed in the alluvial and alluvial fan deposits overlying the San Pedro Formation sediments, we can obtain a minimum age for the marine sediments at this location, and thus an understanding of the geological history of the area.

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We described the soil profiles according to the characteristics and nomenclature set forth by the Soil Survey Staff (1975, 1992) and Birkeland (1984, 1999). Colors of the soil horizons and parent materials were recorded using a Munsell Soil Color Chart. We looked for, among other characteristics, the amount and thickness of translocated clay and silt, the presence of clay films or stains on soil ped faces and clasts and in between sand grains (referred to as bridges), the color (reddening) of the soils, and the looseness or induration of the sediments.

Soil development index (SDI) values were calculated for the soil profiles based on the field descriptions using a modified version of the Harden (1982) index, and the maximum horizon index (MHI) of Ponti (1985). Both SDI and MHI values have been shown to be useful relative indicators of age when comparing soils developed in similar parent materials under similar climatic conditions (Bornyasz and Rockwell, 1997; Rockwell et al., 1990; Rockwell et al., 1984; Harden, 1982). Minimum age estimates for the deposits were made by comparing the SDI and MHI values obtained at the site with those of dated regional soils developed under similar conditions (Dolan et al., 1997; Dolan et al., 2000, and the soil age regressions referenced therein).

The soil profiles described are summarized as follows:

1. Profile 1: On the south wall of Trench T-1 at station 0+44, on the dissected alluvial fan to the west of the main escarpment that extends through the campus.

2. Profile 2: On the south wall of Trench T-2 at station 2+70, near the base of the east-facing scarp that extends in a northerly direction across the front of the school, near Moreno Road.

3. Profile 3: On the north wall of Trench T-2 at station 3+45, farther east than Profile 2 above. Like Profile 2, this one exposed a younger alluvial section underlain by two older alluvial packages.

4. Profile 4: The soils exposed in boring CB-3. This boring was drilled to a depth of 120 feet. Soil descriptions were made to a depth of 80.5 feet (24.5) meters, to the top of the sand assigned to the San Pedro Formation (Qsp1). Nine separate soils were identified in the alluvial section described. The soils varied in their degree of development and thickness.

Summarized soil descriptions for these profiles are provided in Table 1. The complete soil descriptions for each of these profiles are included as Appendix A. The soils exposed in Trench T-3 were reviewed but not described because the soils therein have been modified, limiting our ability to obtain a representative age for the geologic materials. Specifically, the uppermost soil horizons in that area appear to have been removed, and the underlying soil horizons exposed in the trench had been leached. Both of these conditions would yield much lower age estimates. The soils in Trench T-1 were better preserved and thus deemed to provide a much better age estimate for the geomorphic surface upon which a large portion of the school is founded.

FINDINGS

The soil profiles and depositional materials reviewed and described for this project can be separated into two groups, as follows:

1. The soils described in Profiles 2 and 3 developed in relatively young alluvial sediments deposited as fill in the channel of Benedict Canyon, a drainage that incised into the older alluvial sediments described in Trench T-1 and boring CB-3. The soils described in Profiles 2 and 3 (and in the eastern end of the trench T-2) indicate that the near-surface sediments in this area of the high-school campus consist of younger alluvial deposits underlain by two older alluvial packages.

   Soil development in each of these alluvial packages indicates a hiatus in deposition between each section, allowing for soil development to occur before the next, overlying alluvial sediments were deposited. The age estimates developed for the older alluvial packages are minimum age values given that these ages represent only the length of time that the sediments and soils were exposed to soil-forming processes at the surface. The age estimates based on degree of soil development do not provide data on how long it took for the alluvial sediments to be deposited, nor does it account for any periods of infilling and cutting that are no longer preserved in the section. The entire section is younger than the sediments exposed in trench T-1 and boring CB-3.

2. Soil Profile 1 (from Trench T-1) and the soils sequence in boring CB-3 developed in older alluvium, with the near-surface soil in both of these exposures having been exposed to soil-forming processes for a long time. Specifically, Trench T-1 exposed a soil with 7.5YR to 5YR hues, strong coarse to very coarse angular blocky structure, and many moderately thick clay films on ped faces, bridging grains and in pores. The uppermost horizon preserved in the trench, under artificial fill, consists of an incipient E horizon that is forming at the expense of the argillic horizon below. The overlying A horizon has been removed, most likely during construction of the school. The age estimates developed for this profile using soil development indices are considered minimum values given that the soil is truncated and it is currently undergoing leaching of the illuviated clay.

   The uppermost soil described in boring CB-3 is correlative with the soils exposed and described in Profile 1, as this boring was emplaced near the east end of Trench T-1, but the soil in the boring exposed a thicker argillic section and extended to a depth of 4.72 m (15.5 ft), deeper than the bottom of trench T-1. The E soil horizon observed in trench T-1 was not observed in the core of boring CB-3, possibly in part because the upper 2 feet of the boring were not recovered.

   Altogether, the soils in boring CB-3 consist of a stacked sequence of weakly to well-developed soils that rest one upon another, separated by slightly altered to unaltered alluvial fan or fluvial sediments (the parent material). The soils represent periods of sub-aerial weathering and soil formation that occurred in between periods of alluvial erosion and deposition. The entire sequence of stacked soils combined provides a minimum age for the underlying marine sediments assigned to the San Pedro Formation. The buried soils (starting with the second soil) described in boring CB-3 are summarized in the following paragraphs.

The second soil described exhibits a thick argillic section (1.73 m; 5.7 ft), 7.5YR hues, and common to many moderately thick clay films bridging grains. The third soil down the section is thin (69 cm; 27 inches) and less well-developed, with 10YR to 7.5YR hues, few thin clay films on ped faces and many thin clay films bridging grains. The fourth soil, which began at a depth of 7.37 m (24.2 ft), is very well developed, with a 2.05 m (6.7 ft) argillic section, colors in the 7.5YR to 5YR hues, common to many clay films on ped faces, and many to continuous clay films bridging grains. The fifth soil is relatively thin and weakly developed, with only an 18-cm (7-inch) thick argillic section preserved, 10YR hues, and common to many thin clay films on ped faces and many moderately thick clay films bridging grains. Some of these clay films are probably the result of overprinting, whereby clay from the overlying, much better developed soil moved down into this soil.

The sixth soil in the sequence is also relatively thin, with an argillic section only 40 cm (15.7 inches) thick, but the 7.5YR hues and many to continuous moderately thick clay films bridging grains and many thin clay films on ped faces suggest that this was a well-developed soil of which only the bottom part of the profile remains. The argillic section is underlain by a 4.37 m (14.3 ft) thick section of oxidized parent material with 7.5YR Bt lamellae, each 5 to 13 cm (2 to 5 inch) thick. The seventh soil, by contrast, has a well-developed, pedogenic clay-rich argillic section 145 cm (4.75 ft) thick with 10YR-7.5YR hues and 5YR mottles. This soil also has strong angular blocky structure, many moderately thick clay films on ped faces, common to many moderately thick clay films bridging grains, and few scattered calcium carbonate nodules. The eight soil consists of a thick (1.63 m; 5.4 ft) argillic section with 2.5Y to 10YR hues, 7.5YR mottles, and many moderately thick clay films. The ninth (and last) soil in the section has a 53-cm (21 inch) thick argillic section with calcium carbonate nodules and stringers.

Table 1: Soil Descriptions
Soil Profiles Described at Beverly Hills High School

	Depth (cm)	Thickness (cm)	Texture	Color Moist	Color Dry (sm = slightly moist)	Structure	Consistency Dry	Consistency Moist	Consistency Wet	Wet	Clay Films	Comments
Soil Profile 2 - Trench T-2												
2A/Btj1	50 - 98	48	CL	10YR 2/2	10YR 4/3 & 3/2	3f-mabk	so	fr-sfi	s	p	2npf, 3npo	
2Btj2	98 - 123	25	SCL	7.5YR 3/2	10YR 4/3& 3/3, 7.5YR 3/	2mabk	so-sh	fr-sfi	s	p	1npf, 3mkpo	
2Bt	123 - 141	18	CL-C	10-7.5YR 3/2	10YR 4/3 & 7.5YR 3.5/2	2f-mabk	h	sfi	s	p-vp	2mkbr, 2npo, 2n&1mkpf	
3Ab	141 - 155	14	CL-C	10YR 3/2	10YR 4/3	2msbk		fr	s	p-vp	no clay films	
3BCb1	155 - 179	24	SC-C	7.5YR 3/2	10YR 4/3	1fmsbk		vfr	vs	p-vp		
3BCb2	179 - 237	58	CL	7.5YR 3/3	10YR 4/3	1fmabk		fr	s	p	2nst	
4Btb1	237 - 278	41	gC	7.5YR 3/2 & 3/3	10YR 4/4	3cabk	eh	efi	vs	vp	3mkpf&po, 2mk&3nbr	
5BClam1	278 - 293	15	SCL & SC	7.5YR 3/2 & 3/4	10YR 4/4 & 3/4	m-2mcabk	lo-so & sh	vfr & sfi	s & vs	p & vp	3n-mkpf, 3nbr	
6BCb3	293 - 304	11	siC	10YR 3/3, 3/4 & 7.5YR 3/2		m		fr	s	p-vp	2nst, 3mkcl	
7Btb2	304 - 329	25	gSC	7.5YR 4/4, 3/3 & 3/2		2m-cabk		fr	vs	p	3npf, 3npo, 3mkbr	
7BCb4	329 - 350	21	SL-SCL	7.5-10YR 3/4		sg, 1f-msbk		lo-vfri	ss	sp	2nst, 3mkpo	Moist when sampled and described
7BClam2	350 - 371	21	SCL & C	10YR 3/3 & 7.5YR 3/4		sg & 2cabk		vfr	s	p	3npf&po, 3mkbr	
8Clam1	371 - 388	17	gSL-SCL	10YR 3/3 & 7.5YR 3/2		sg & 2f-msbk		lo & vfr	ss & vs	sp & sp	3mkpf&po, 2-3mkbr, 4ncl	
9Cox1	388 - 401	22	SL - SiL	10YR 3/3		sg		lo-vfr	ss	np		
10Clam2	401 - 416	15	SiL	10YR 3/4 & 7.5YR 3/2		m		lo-vfr	ss-s	np	3npf	
10Cox2	416 - 440+	24	SCL	10YR 3/3		m		vfr	ss	p	3npo	
Soil Profile 3 - Trench T-2												
A/Btj1	25 - 41	16	CL	10YR 2/2	7.5-10YR 3/2	2msbk	h	fi-vfi	s	p-vp	3ncl	
Btj2	41 - 65	24	CL-C	10YR 3/2 & 10YR 3/2	10YR 5/4	2cabk	vh-eh	efi	vs	p-vp	4mkpo	
2Ab1/2Bt1b	65 - 88	23	C	10YR 2/2	10YR 3/2	2mabk-2fabk	vh	vfi	vs	vp	3nst	
2Btb2	88 - 114	26	C	10YR 2/2	10YR 3/3& 2/2	3cabk	vh	vfi	vs	vp	3n&2mkpf, 2mkpo	
3Ab2	114 - 161	47	CL-C	10YR 2/2		2f-mabk - 2cabk	so-sh	fr	s-vs	p	no clay films	
4Btb3	161 - 193	32	C	7.5YR 3/2	7.5YR 3/1 & 3/2	3m-cabk	eh	efi	vs	vp	3mkpf, 4mkpo, 3-4mkbr	
4Btb4	193 - 230	37	C	7.5YR 3/2	7.5YR 3/1& 3/2	3vcabk-3mpr	eh	efi	vs	vp	3n-mkpf, 3mkpo&br	
4Btb5	230 - 260	30	C	10YR 3/3 & 7.5YR 3/2	7.5YR 3/3	3c-vcabk-pr	so-sh	fri	s	p	3mkpf&br, 4mk-kpo	
4BCb1	260 - 297	37	SCL	7.5YR 3/2.5	7.5YR 4/4 & 3/2 sm	2cabk-pr, 3mabk	so-sh	fri	s	sp	2mk&3npf, 3npo, 2-3ncl, 3n-mkbr	
4BCb2	297 - 315	18	SiCL - SiC	7.5YR 3/3& 3/2.5	7.5YR 4/6	2mabk	so-sh	fri	s	p-vp	1-2npf	charcoal sample collected
4Cb1	315 - 367	52	SC - SCL	10-7.5YR 3/3	10-7.5YR 3/4 sm	2mabk		fr	s	p	2npo&st	
4Cb2	367 - 385	18	SCL	7.5-10YR 3/3	7.5-10YR 4/4 sm	1-2fsbk		fr	s	sp-p	1st	
5Cb3	385 - 397	12	S	10YR 3.5/2	10YR 5/4	sg	lo	lo	ns	np	no clay films	
6Cb4	397 - 437+	40	gS	10YR 3/4	10YR 3/3	sg & 1m-cabk	lo-so	lo-vfr	ns	np	no clay films	charcoal and OSL samples collected

ABBREVIATIONS
TEXTURE: g = gravel or gravelly; S= sand; LS = loamy sand; SL = sandy loam; L = loam; SCL = sandy clay loam; SC = sandy clay; CL = clay loam; Si = silt; SiL = silt loam; SiCL = silty clay loam; SiC = silty clay; C = clay. **STRUCTURE**: **Grade**: 1 = weak; 2 = moderate, 3 = strong. **Class**: 1f = very fine, f = fine, m = medium, c = coarse; vc = very coarse. **Type:** m = massive; sg = single-grained; gr = granular, cr = crumb, abk = angular blocky, sbk = subangular blocky, pr = prismatic. **CONSISTENCY**: **Dry**: lo = loose, so = soft, sh = slightly hard, h = hard, vh = very hard, eh = extremely hard. **Moist**: lo = loose, vfr = very friable, fr = friable, fi = firm, vfi = very firm, efi = extremely firm. **Wet**: ns = non-sticky, ss = slightly sticky, s= sticky, vs = very sticky; np = non-plastic, sp = slightly plastic, p = plastic, vp = very plastic. **CLAY FILMS: Abundance:** v1 = very few, 1 = few, 2 = common, 3 = many, 4 = continuous. **Thickness**: vn = very thin, n = thin, mk = moderately thick, k = thicK. **Location**: st = stains, cl = on clasts or clast pockets, po = in pores, br = forming bridges betweeen grains, pf = on ped faces.

Table 1: Soil Descriptions
Soil Profiles Described at Beverly Hills High School

Horizon	Depth (cm)	Thickness (cm)	Texture	Color Moist	Color Dry (sm = slightly moist)	Structure	Consistency Dry	Consistency Moist	Consistency Wet	Consistency Wet	Clay Films	Comments
Soil Profile 1 - Trench T-1												
Ej	11 - 35	24	CL	7.5YR 3/2	10YR 4/4	m-2fmabk	h	fi	ss-s	sp-p	3-4npo, 2-3nbr	
Bt1	35 - 97	62	C	5YR 3/2	5YR 3/3	3c-vcabk	eh	efi	vs	vp	2kpf, 3npf, 4mkpo	
Bt2	97 - 145	48	SC	5YR 3/4 & 2.5Y 3/1		3cabk-3fabk		fi	vs	vp	1mkpf, 3npf, 3mkbr, 3mkpo	Moist when sampled
2Bt3/E	145 - 201	56	SC	7.5YR 3/3	7.5YR 5/4	3cabk	sh	fr	s	p	3mkbr, 2npf	
3Bt4	201 - 254	53	SC	10YR 3/4	7.5YR 3/4	2mabk	sh-h	fr	s	p	2mkpf, 2n-mkbr	
4BClam1	254 - 266	12	SL & SCL	7.5YR 3/4	7.5YR 4/6	sg & 1-2mabk	lo & so-sh	lo & vfr	ns & ss	np & np-sp	1npf, 2n-mkbr	
5BClam2	266 - 305	39	SG & SCL	7.5YR 4/4	7.5YR 3/4	sg & 1-2msbk	lo & sh	lo & fr	ns & ss	np & np	1npf, 2-3nbr, 3mkcl	
6BClam3	305 - 335	30	SG & SCL	7.5YR 4/4 & 5YR 3/2.5	7.5YR 4/6 & 5YR 3/3	sg & 2-3msbk	lo & h	lo & fr	ns & ss	np & np	2mkpf	
7BClam4	335 - 372	37	SL-L & CL	10YR 3/3 & 3.5/3	10YR 4/4 sm	3f-msbk		fr-fi	ns-ss	sp	2mkbr&po	
7BClam5	372 - 403	31	SL-L & CL	10YR 3/3	10YR 4/4	-2mabk & 3f-mab	so	vfr	ns	sp	3n-mkpf, 3-4npo	
8BClam6	403 - 421+	18	gS & C	7.5YR 3.5/4	7.5YR 4/3 & 5YR 3/3	sg & 3mabk	lo & h-vh	lo & fr	ns & ss-s	np & p	1ncl, 3nbr	
Soil Profile 4 - Boring CB-3												
Bt1	61 - 109	48	gC	10YR 3/2	7.5YR 4/4 m		vh		s	p	2mkb, 2mk-3npf	
Bt2	109 - 152	43	gSCL	10YR 3.5/3 & 7.5YR 4/4	10YR 6/2 & 5YR 5/6			fr				
2Bt3	165 - 264	99	Cg	5YR 4/4	7.5YR 3.5/4	sg		fr				
3Bt4	264 - 305	41	SC	7.5YR 3.5/4	5YR 4/4	2f-mabk					3nbr	
4BC1/Btlam	356 - 472	116	siC, SC	7.5YR 3/4	7.5YR 4/4						2nbr	
5Bt5	472 - 508	36	siC - C	7.5YR 4/4	7.5YR 4/6				vs	vp		
5Bt6	508 - 528	20	SiC - SC	10-7.5YR 4/4	10-7.5YR 4/4				vs	p-vp	2npf, 2-3mkbr	
5Bt7	528 - 597	69	SC-C	10-7.5YR 4/4	10-7.5YR 4/3.5				vs	p-vp	2mkbr	
6Bt8	597 - 645	48	gSC	10-7.5YR3/4	10-7.5YR 4/4				s-vs	p	2-3mkpf, 3mkbr	
6BC2	645 - 668	23	gS, LS-SL	10-7.5YR 4/3	10-7.5YR 3.5/3	sg - 1-2fabk	lo	lo	ns	np		
7Bt9	668 - 691	23	SC	10-7.5YR 3.75/5	10-7.5YR 4/4				s-vs	sp-p	1npf, 3nbr	
7C1	691 - 721	30	fiSC	10YR 4.5/3	10YR 5/4							
7C2	737 - 721	16	SCL	10YR 3.5/4	10YR 4/4				s	sp		
8Bt10	737 - 841	104	C	10-7.5YR 4/4	7.5YR 3/3		vh-eh	vfi-efi	vs	vp	3n&2mkpf, 3mkbr	
9Bt11	841 - 886	45	C	7.5YR 4/3	10YR 5/2.5	3cabk	eh	efi	vs	vp	4mkpo, 3mkpf	
9Bt12	886 - 942	56	SC-C	7.5YR 4/3	7.5YR 5/4	3cabk - 2mcsbk			s	p	3npf, 3mkbr	
10BC3	942 - 1049	107	gSCL	10YR 4/4	10YR 5/4		vh	fr	s	sp-p	2mkbr, 3mkcl	
11Bt13	1049 - 1067	18	gC	10YR 3/4	10YR 4/4		vh	vfi	s	p-vp	3mkbr, 2npf	
11BC4	1067 - 1123	56	SCL	10YR 3/4	10YR 4/4		h	vfr-fr	s	np-sp	1-2npf, 3-4mkbr	
12Bt14	1123 - 1163	40	SiC - C	7.5YR 3.5/3	7.5YR 4/3	3cabk			vs	p-vp	3-4mkbr, 2mk&3npf	
13C3lam	1163 - 1600	437	Si	10YR 5/4	10YR 5/6				vs	sp		
14Bt15	1600 - 1692	92	C	7.5YR 3/3	10YR 3/3		vh-eh	vfi-efi	vs	vp	3mkbr, 3-4mkpf	
14Bt16	1692 - 1745	53	C	10YR 4/3	7.5YR 5/4				vs	vp	1mk&2npf, 2mkbr	
14BC5	1745 - 2047	302	Si-C	2.5Y-10YR 5/3.5	2.5Y-10YR 6.5/3	1-2cabk - m	vh-eh	efi	vs	p-vp		
15Bt17	2047 - 2096	49	C	10YR 4/3	10YR 5/3	2mabk-3fabk			vs	vp	3n&2mkbr	
15Bt18	2096 - 2164	68	C	10-7.5YR 3.5/3.5	10YR 4/3.5	2-3cabk	eh	efi	vs	vp		
15Bt19	2164 - 2210	46	C	2.5Y-10YR 3/2		3fabk	eh	efi	vs	vp	3mk-kpf, 3-4mkbr	
15C4	2210 - 2233	23	S	2.5Y-10YR 6.5/3		m, sg	lo-so	lo-vfr	ns	np		
16Bt20	2233 - 2268	35	SiC	10YR 4.25/2.5	10YR 4.75/3	3cabk			vs	vp		
16Btk	2268 - 2286	18	SiC		2.5Y 6/2 & 7.5YR 6/4				vs	p-vp	3 f-m calcium carbonate nodules and stringers	
16BC6	2286 - 2291	5	S									
16BC7	2291 - 2426	135	C		2.5Y 5/1, 4/1 &10YR 6/8	3fabk					3-4mkbr	
17C5	2426 - 2438	12	SC	2.5Y 5/3	2.5Y 6/2		vh-eh	fr	ss	p		
18C6	2454+		S (Qsp)	5Y 6/2	2.5Y 7/2	sg						

AGE ESTIMATES

The near-surface soil observed in Trench T-2 and described in Profiles 2 and 3 has an approximate age of between 9,500 (Profile 2) and 12,500 (Profile 3) years. Minimum and maximum ages for this soil, defined by the envelopes that capture 95 percent of the data used to develop the soil regressions (Dolan et al., 1997), are 3,000 and 37,500 years, respectively (see Table 2).

The first of the two soils developed in the slightly older alluvium exposed in Trench T-2 was exposed at the surface for approximately 11,000 years before being buried. Minimum and maximum ages for this soil are 3,500 and 34,500 years, respectively.

The second, and deeper of the two soils developed in slightly older alluvium exposed in Trench T-2 was exposed to soil-forming processes at the surface for approximately 16,000 (Profile 2) to 28,000 (Profile 3) years before being buried. Minimum and maximum ages for this soil are 5,000 and 88,000 years, respectively, using the soil age estimates derived from the Soil Development Index (SDI) regressions.

This means that the entire alluvial sequence exposed at the east end of Trench T-2 is, at a minimum, between about 36,500 and 51,500 years old using the average ages of each separate soil described therein.

The older alluvium exposed in Trench T-1 and near the surface in boring CB-3 has been exposed to soil-forming processes for at least 68,500 years (based on the minimum horizon index - MHI, which we prefer in this instance given that the top of the soil has been truncated and the top of the argillic horizon is being modified into an E horizon). The equivalent soil at the top of boring CB-3 has an approximate age of between 72,750 years (using the MHI regression curve) and 107,000 years (using the SDI regression curve).

Each of the now-buried soils described in the core of boring CB-3 was exposed at the surface for sufficient time to develop argillic soil horizons. The age estimates for each of these buried soils vary from a minimum average age of 30,000 years (Qoal5) to 133,000 years (Qoal6) using the values calculated from the SDI regression curve. The MHI regression curve for the same soils yields age estimates for these buried soils that range between about 47,000 and 419,500 years. The combined ages of these buried soils indicate that the entire alluvial section exposed in boring CB-3 is at a minimum between about 530,000 years (using the SDI regression curves) and 1.3 million years old (using the MHI regression curves). This in turn provides an absolute minimum age for the underlying San Pedro Formation sand. We prefer the first value because it is consistent with the 400,000 to 900,000 years age estimate for the marine abrasion platform that has been observed in borings drilled east of the Beverly Hills High School site, in the West Hollywood area of Los Angeles (Lindvall et al., 2001, based on work conducted by Earth Consultants International, William Lettis & Associates, MACTEC, and others). This minimum age estimate is also consistent with the minimum age of 600,000 years for the top of the San Pedro Formation reported by Ponti (1989) for the Wilmington/Dominguez Gap and Signal Hills areas. Given that the San Pedro Formation is a chrono-stratigraphic unit that becomes younger westward, and given that the Beverly Hills area is farther inland than the Dominguez Gap and Signal Hills areas, the age of the San Pedro Formation in the site vicinity should be more than 600,000 years old.

Table 2: Age Estimates for the Soils Described in this Study
(ages rounded to the nearest 500 years)

Soil	SDI	MHI	Average Age (years)	Minimum Age (years)	Maximum Age (years)
Profile 2 (T-2)					
Qal1	25.5		12,500	4,000	37,500
		0.29	11,500	4,000	36,000
Qal2	23.8		11,000	3,500	34,000
		0.26	10,000	3,000	31,500
Qal3	48.1		16,000	5,000	51,000
		0.60	64,000	20,500	197,000
Totals for the section (based on preferred ages, using the SDIs)			39,500	12,500	122,500
Profile 3 (T-2)					
Qal1	15.5		9,500	3,000	31,500
		0.4	22,000	7,000	62,500
Qal2	19.7		11,000	3,500	34,500
		0.44	26,000	8,500	70,000
Qal3	85.1		28,000	9,000	88,000
		0.63	77,000	24,500	255,000
Totals for the section (based on preferred ages, using the SDIs)			42,000	22,500	154,000
Profile 1 (T-1)					
Qoal1	94.8		39,000	12,000	125,000
		0.61	68,500	22,000	220,000
Preferred age (based on the MHI, given that the soil was truncated)			68,500	22,000	220,000
Profile 4 (CB-3)					
Qoal1					
	166.5		107,000	33,000	350,000
		0.62	73,000	23,250	238,000
Qoal2	124		52,500	17,500	171,000
		0.77	187,500	51,500	533,500
Qoal3	102.2		38,000	12,500	119,500
		0.74	141,500	45,000	483,000
Qoal4	134.3		64,000	20,500	203,000
		0.70	120,000	33,000	384,500
Qoal5	87		30,000	9,500	94,500
		0.54	47,000	14,500	128,500
Qoal6	180.1		133,000	40,500	442,500
		0.95	419,500	132,500	1,750,000
Qoal7	145.2		76,000	24,000	243,000
		0.75	165,000	46,500	527,000
Qoal8	102.5		38,500	12,500	120,500
		0.64	94,500	29,500	313,000
Qoal9	96.3		35,000	11,000	108,500
		0.58	59,000	18,500	191,000
Total age for the entire alluvial section above the San Pedro Formation (using MHI values)			1,307,000	394,000	4,548,000
Total age for the entire alluvial section above the San Pedro Formation (using the SDI values)			530,000	167,500	1,723,000

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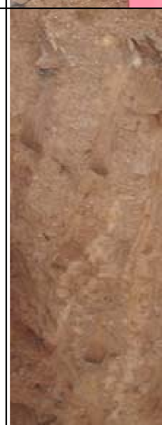
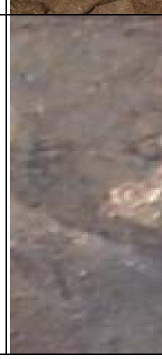
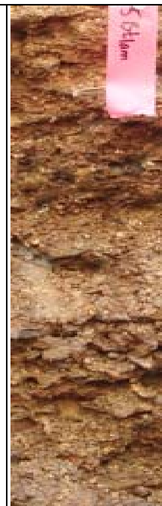
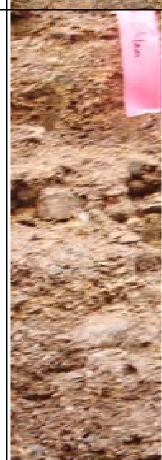
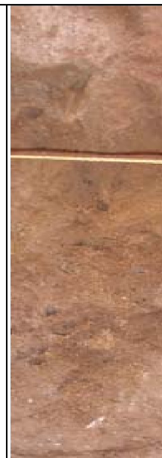
APPENDIX A:
Beverly Hills High School Trenching Project
SOIL PROFILE DESCRIPTIONS

Profile No. 1 – Leighton's Trench 1, South Wall at approximately Station 0+44.
On dissected alluvial fan above main escarpment; near highest elevation at school.

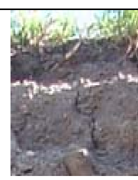
Depth (ft)	Depth (cm)	Horizon Designation	Photo	Description
0 – 0.36	0 – 11	Ap (Afu)		Gravelly clayey sand with scattered nails and pieces of wire. No samples collected. Abrupt smooth boundary.
0.36 – 1.15	11 - 35	Ej		CLAY LOAM; dark yellowish brown (10YR 4/4) with many distinct fine reddish brown, yellowish red and grayish brown (5YR 4/4, 5YR 4/6 and 10YR 5.5/2) mottles when dry, dark brown (7.5YR 3/2) when moist; massive breaking to moderate fine to medium angular blocky structure; hard when dry, firm when moist, slightly sticky to sticky and slightly plastic to plastic when wet; many to continuous thin clay films in pores, common to many thin clay films bridging grains; very few calcium carbonate nodules; common fine pinhole pores; seems to be section of an argillic horizon undergoing leaching of clay; abrupt wavy to irregular boundary.
1.15 - 3.18	35 - 97	Bt1		CLAY; dark brown (7.5YR 3/2) to dark reddish brown (5YR 3/3) when dry, dark brown (7.5YR 3/2) to dark reddish brown (5YR 3/2), with few black mottles when moist; strong coarse to very coarse angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; common thick and many thin clay films on ped faces, continuous moderately thick clay films in pores; common very fine pinhole pores; gravel content increases downward; redder and stronger structure reported above is for soil to the west of where this profile was made; abrupt to clear and wavy boundary.
3.18 – 4.76	97 – 145	Bt2		SANDY CLAY; dark reddish brown (5YR 3/4) with common (30%) coarse very dark gray (2.5Y 3/1) gleyed mottles when moist, dark brown (10YR 3/2) when wet and mixed; strong coarse angular blocky breaking to strong fine angular blocky structure; firm when moist, very sticky and very plastic when wet; few moderately thick and many thin clay films on ped faces, many moderately thick clay films bridging grains and in pores; abundant angular to subangular gravel; moist when sampled; clear and wavy boundary.

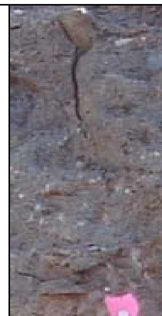
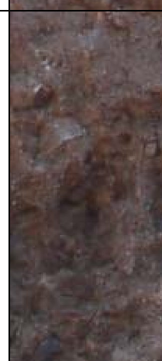
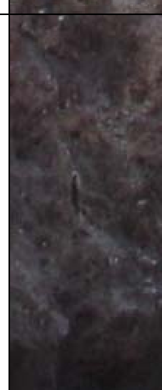
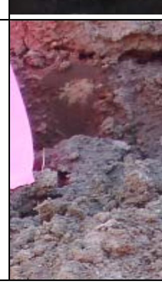
4.76 – 6.59	145 – 201	2Bt3/E		Argillic horizon with albic tongues. Argillic section: SANDY CLAY; dark brown (7.5YR 5/4) with few dark reddish brown (5YR 3/3) mottles when dry, dark brown (7.5YR 3/3) when moist; strong coarse angular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; common thin to moderately thick dark brown (7.5YR ¾) clay films bridging grains increasing downward to many moderately thick, common thin clay films on ped faces at bottom; less gravel than horizon above, with scattered rounded to subrounded gravel to 2.5-cm in diameter. Albic tongues: SANDY LOAM, yellowish brown (10YR 5/4) when dry; single-grained structure; loose when dry and moist, non-sticky to slightly sticky and non-plastic when wet; abrupt and wavy boundary.
6.59 – 8.33	201 - 254	3Bt4		CLAYEY GRAVEL (slaty gravel surrounded by pedogenic clay); dark brown and brown (7.5YR 3/4 and 10YR 4/3) with dark reddish brown (5YR ¾) mottles when dry, dark yellowish brown (10YR 3/4) when moist and mixed; moderate medium angular blocky structure; slightly hard to hard when dry, friable when moist, sticky and plastic when wet; common moderately thick clay films on ped faces, common thin to moderately thick clay films bridging grains; gravel predominantly angular, fining downward; abrupt to clear wavy boundary.
8.33 – 8.73	254 - 266	$4BC_{lam}1$		SANDY LOAM with SANDY CLAY LOAM Bt lamellae; strong brown (7.5YR 4/6) when dry, dark brown (7.5YR 3/4) when moist; single-grained, weak to moderate fine angular blocky structure where Bt_{lams} are present; loose when dry and moist, non-sticky and non-plastic when wet; Bt_{lam} sections are soft to slightly hard when dry, very friable when moist, slightly sticky and non-plastic to slightly plastic when wet; Bt_{lam} sections have few thin clay films on ped faces and common thin to moderately thick clay films bridging grains; abrupt wav to irregular boundary (this horizon was locally eroded away by overlying mudflow deposit).

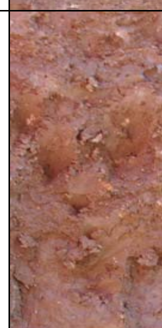
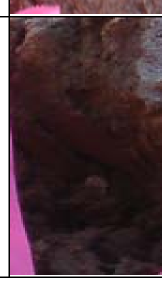
8.73 – 10.01	266 – 305	$5BC_{lam}2$		Fine to coarse SANDY GRAVEL with SANDY CLAY LOAM Bt lamellae; clay is dark brown (7.5YR 3/4) when dry, brown (7.5YR 4/4) when moist; single-grained, weak to moderate medium subangular blocky structure where Bt_{lams} are present; sandy gravel is loose when dry and moist, non-sticky and non-plastic when wet; Bt_{lam} peds are slightly hard when dry, friable when moist, slightly sticky and non-plastic when wet; Bt_{lam} sections are 2- to 5-cm thick, occur especially at the top of the horizon and marking the bottom contact, non-Bt_{lam} sections are 1- to 6-cm thick; few thin clay films on ped faces, common to many thin clay films bridging grains, and many moderately thick clay films coating clast pockets in the Bt_{lam} sections; clasts are angular to subrounded; abrupt and smooth to wavy boundary.
10.01 – 10.99	305 – 335	$6BC_{lam}3$		SANDY GRAVEL with SANDY CLAY LOAM Bt lamellae; strong brown (7.5YR 4/6) when dry, brown (7.5YR 4/4) when moist, clay in Bt_{lam} is dark reddish brown (5YR 3/3) when dry, dark reddish brown (5YR 3/2.5) when moist; single-grained, moderate to strong medium subangular blocky structure where Bt_{lams} are present; sandy gravel is loose when moist, non-sticky and non-plastic when wet, Bt_{lam} peds are hard when dry, friable when moist, slightly sticky and non-plastic when wet; Bt_{lam} sections are about 5-cm thick, separated by non- Bt_{lam} sections about 3-cm thick; common moderately thick clay films on Bt_{lam} peds; similar to unit above except clasts are rounded to subrounded; abrupt and smooth to wavy boundary.
10.99 – 12.20	335 – 372	$7BC_{lam}4$		Fine SANDY LOAM to LOAM with few CLAY LOAM Bt lamellae; dark yellowish brown (10YR 4/4) when moist, dark brown (10YR 3/3) when wet, clay on ped faces in Bt_{lams} is dark brown to brown (10YR 3.5/3) when moist; strong fine to medium subangular blocky structure where Bt_{lams} are present; friable to firm when moist, non-sticky to slightly sticky and slightly plastic when wet; Bt_{lams} have common thin clay films on ped faces, common moderately thick clay films bridging grains and in pores; some primary sedimentary structures still visible; clear and wavy boundary with channel lag at bottom.

12.20 – 13.22	372 – 403	$7BC_{lam}5$		Fine SANDY LOAM to LOAM with few CLAY LOAM Bt lamellae; dark yellowish brown (10YR 4/4) when dry, dark brown (10YR 3/3) when moist; weak to moderate medium angular blocky structure, strong fine to medium angular blocky structure where Bt_{lams} are present; soft when dry, very friable when moist, non-sticky and slightly plastic when wet; Bt_{lams} have many thin to moderately thick clay films on ped faces, many to continuous thin clay films in pores; many very fine pinhole pores; with scattered subrounded to rounded gravel to 2.5-cm diameter; remnant, together with horizon above, channel bank deposit cut into and removed to the west, at about station 0+48; abrupt and wavy boundary.
13.22 – 13.81+	403– 421+	$8BC_{lam}6$		GRAVELLY coarse SAND with CLAY Bt lamellae; brown (7.5YR 4/3) when dry, dark brown to brown (7.5YR 3.5/4) when moist, with dark reddish brown (5YR 3/3) clay when dry; single-grained, strong medium angular blocky structure where Bt_{lams} are present; loose when dry and moist, non-sticky and non-plastic when wet, Bt_{lam} peds are hard to very hard when dry, friable when moist, slightly sticky to sticky and plastic when wet; Bt_{lam} zones are 2-10 cm thick; Bt_{lams} have few thin clay films on clasts, common thin clay films bridging grains; clasts are predominantly subangular to subrounded.

Profile No. 2 – Leighton's Trench 2, South Wall at approximately Station 2+70.
On flat area at base of east-facing scarp; soil developed in younger alluvial deposits.

Depth (ft)	Depth (cm)	Horizon Designation		Description
0 – 0.33	0 - 10	Ap1		Fine gravelly SANDY LOAM to LOAM; dark grayish brown (10YR 4/2) when dry, very dark brown (10YR 2/2) when moist; moderate coarse crumb breaking to strong fine crumb structure; very hard when dry, very firm when moist, sticky and slightly plastic when wet; mixed in composition, locally with argillic-like soil clasts that have common thin clay films on ped faces; abundant roots and rootlets; gravel is angular to subrounded, most less than 0.5 cm in diameter; with plastic netting at about 4 cm below ground surface to grab grass roots; abrupt and smooth to wavy boundary.

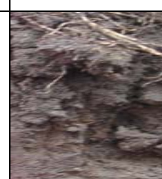
0.33 – 1.64	10 - 50	Ap2		CLAY LOAM with gravel and cobbles; dark grayish brown (10YR 4/2) when dry, very dark brown (10YR 2/2) when moist; strong coarse angular blocky structure; very hard when dry, very firm when moist, sticky and plastic when wet; many thin clay films on ped faces; abundant roots throughout, brown (7.5YR 4/4) next to roots and root mats; few worm casts; with pipes near bottom contact and scattered metal objects within; clear and smooth to wavy boundary.
1.64 - 3.22	50 - 98	2A/Btj1		CLAY LOAM; brown and very dark grayish brown (10YR 4/3 and 10YR 3/2) equally when dry, very dark brown (10YR 2/2) when moist; strong fine to medium angular blocky structure; soft when dry, friable to slightly firm when moist, sticky and plastic when wet; common thin clay films on ped faces, many thin clay films in pores; very few fine manganese oxide stains; pinhole porosity; primary sedimentary structure still visible locally, with rip-up clasts and scattered angular gravel; many rootlets; clear and wavy boundary.
3.22 – 4.04	98 – 123	2Btj2		SANDY CLAY LOAM; brown to dark brown (10YR 4/3 to 3/3) with dark brown (7.5YR 3/2) clay on ped faces when dry, dark brown (7.5YR 3/2) when moist; moderate medium angular blocky structure; soft to slightly hard when dry, friable to slightly firm when moist, sticky and plastic when wet; few thin clay films on ped faces, many moderately thick clay films in pores; iron oxide staining along root-holes; primary sedimentary structure still visible locally; scattered angular gravel, coarser sand than above; clear and wavy boundary.
4.04 – 4.63	123 – 141	2Bt		CLAY LOAM to CLAY; brown (10YR 4/3) with dark brown (7.5YR 3.5/2) clay when dry, dark brown to very dark grayish brown (10-7.5YR 3/2) when moist; moderate fine to medium angular blocky structure; hard when dry, slightly firm when moist, sticky and plastic to very plastic when wet; common moderately thick clay films bridging grains, common thin clay films in pores, common thin and few moderately thick clay films on ped faces; manganese oxide staining; many fine pores locally; scattered gravel, but less than horizon above; pockets of coarse sand discernible locally; abrupt to clear and wavy boundary.
4.63 – 5.08	141 - 155	3Ab		CLAY LOAM to CLAY; brown (10YR 4/3) when dry and mixed, very dark grayish brown (10YR 3/2) when moist; moderate medium subangular blocky structure; friable when moist, sticky and plastic to very plastic when wet; common to many very fine pores, locally with very dark gray manganese oxide staining; moist when sampled; few scattered fine rounded chips of slate; finer-grained than overlying horizon; clear and

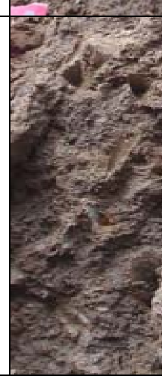
				wavy boundary.
5.08 – 5.87	155 - 179	3BCb1		Very fine SANDY CLAY to CLAY; brown (10YR 4/3) when dry and mixed, dark brown (7.5YR 3/2) when moist; weak fine to medium subangular blocky structure; very friable when moist, very sticky and plastic to very plastic when wet; many pinhole pores; common roots; scattered chips of rounded to subrounded slate; sand more discernible than in overlying horizon; clear and wavy boundary.
5.28 – 7.78	179 – 237	3BCb2		CLAY LOAM; brown (10YR 4/3) when dry and mixed, dark brown (7.5YR 3/3) when moist; weak fine to medium angular blocky structure; friable when moist, sticky and plastic when wet; common thin dark brown (7.5YR 3/2) clay stains on clasts; many pinhole pores; less sand but more slaty gravel than horizon above; abrupt and smooth to wavy boundary.
7.78 – 9.12	237 – 278	4Btb1		Gravelly CLAY; dark yellowish brown (10YR 4/4) when dry and mixed, dark brown (7.5YR 3/2 and 3/3) when moist, with dark reddish brown (5YR 3/2) clay films; strong coarse angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; many moderately thick clay films on ped faces and in pores, common moderately thick and many thin clay films bridging grains; gravel primarily angular; abrupt to clear and wavy boundary.
9.12 – 9.61	278 – 293	$5BC_{lam}1$		SANDY CLAY LOAM with SANDY CLAY Bt lamellae at top; dark yellowish brown (10YR 4/4 and ¾) when dry and mixed, dark brown (7.5YR 3/2 to 3/4) when moist; massive, moderate medium to coarse angular blocky structure where Bt_{lams} are present; loose to soft when dry, very friable when moist, sticky and plastic when wet, Bt_{lam} peds are slightly hard when dry, slightly firm when moist, very sticky and very plastic when wet; Bt_{lams} have many thin to moderately thick clay films on ped faces, many thin clay films bridging grains; abrupt and wavy boundary.
9.61 – 9.97	293 – 304	6BCb3		SILTY CLAY; dark brown to dark yellowish brown (10YR 3/3 to ¾) when moist (no dry color available); massive; friable when moist, sticky and plastic to very plastic when wet; common thin dark brown (7.5YR 3/2) clay stains and many moderately thick clay coatings on clast pockets; abundant fine gravel, mostly subangular to subrounded; moist when sampled; abrupt to clear and wavy boundary.

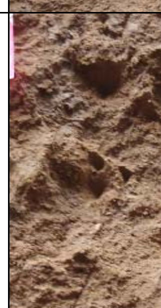
9.97 – 10.79	304 – 329	7Btb2		Gravelly SANDY CLAY; brown and dark brown (7.5YR 4/4 and 3/3) when moist, with dark brown (7.5YR 3/2) clay films; moderate medium to coarse angular blocky structure; friable when moist, very sticky and plastic when wet; many moderately thick clay films bridging grains and in pores, common thin clay films on ped faces; many large pores; moist when sampled; clear and wavy boundary.
10.79 – 11.48	329 – 350	7BCb4		SANDY LOAM to SANDY CLAY LOAM; brown to dark yellowish brown (7.5YR-10YR ¾) when moist; single-grained and weak fine to medium subangular blocky structure; loose to very friable when moist, slightly sticky and slightly plastic when wet; many large pores and common pinhole porosity; common thin stains and many moderately thick clay films in pores; abundant gravel to 2.5-cm in diameter, predominantly angular to subangular, less gravelly than horizon above; moist when sampled; clear and wavy boundary.
11.48 – 12.17	350 – 371	7BC$_{lam}$2		SANDY CLAY LOAM with CLAY Bt lamellae; dark brown (10YR 3/3) when moist; single-grained and moderate coarse subangular blocky structure where Bt$_{lams}$ are present; very friable when moist, sticky and plastic when wet; Bt$_{lams}$ have many thin dark brown (7.5YR ¾) clay films on ped faces and in pores, many moderately thick clay films bridging grains; abundant fine gravel with few clasts to 4-cm in diameter; sand fraction is slightly coarser than horizon above; common to many pinhole pores; moist when sampled; abrupt and smooth to wavy boundary.
12.17 – 12.73	371 – 388	8C$_{lam}$1		Gravelly fine to coarse SANDY LOAM to SANDY CLAY LOAM bracketing a LOAM Bt lamellae 4- to 5-cm thick; dark brown (10YR 3/3) when moist; single-grained except for Bt$_{lam}$ which has moderate fine to medium subangular blocky structure; loose when moist, slightly sticky and slightly plastic when wet, Bt$_{lam}$ material is very friable when moist, very sticky and slightly plastic when wet; Bt$_{lam}$ has many moderately thick dark brown (7.5YR 3/2) clay films on ped faces and in pores, common to many moderately thick clay films bridging grains, and continuous thin coatings on clasts; common pinhole pores in Bt$_{lam}$ section; moist when sampled; abrupt and wavy boundary.
12.73 – 13.16	388 – 401	9C$_{ox}$1		Very fine SANDY LOAM fining upward to SILTY LOAM; dark brown (10YR 3/3) when moist; structureless single-grained; loose to very friable when moist, slightly sticky and non-plastic when wet; scattered fine gravel with many thin clay coatings on clast pockets; common fine pinhole pores; moist when sampled; abrupt and smooth to wavy boundary.

13.16 – 13.64	401 – 416	$10C_{lam}2$		SILT LOAM with Bt lamellae, especially at bottom, at and near contact with underlying horizon; dark yellowish brown (10YR ¾) when moist; massive; loose to very friable when moist, slightly sticky to sticky and non-plastic when wet; Bt_{lams} have many thin dark brown (7.5YR 3/2) clay films on ped faces; many very fine pinhole pores; fewer gravel than horizon above but still present; moist when sampled; clear and wavy boundary.
13.64 – 14.44+	416 – 440+	$10C_{ox}2$		Very fine SANDY CLAY LOAM; dark brown (10YR 3/3) when moist; massive; very friable when moist, slightly sticky and plastic when wet; many fine to medium-sized pinhole pores; many thin clay films in pores; scattered gravel, more than horizon above; moist when sampled.

Profile No. 3 – Leighton's Trench 2, North Wall at approximately Station 3+45.
On flat area to the east of main escarpment; soil developed in younger alluvial deposits.

Depth (ft)	Depth (cm)	Horizon Designation		Description
0 – 0.46	0 - 14	Ap1		Disturbed horizon– not sampled. Moderate to strong fine granular structure at top, in root zone, and moderate fine subangular blocky structure at bottom; mixed horizon with clasts of reddened material; abrupt and smooth to wavy boundary.
0.46 – 0.82	14 - 25	Ap2		Disturbed horizon – not sampled. Gravelly fine to coarse sand with some clay mixed in, especially at bottom; abrupt and wavy boundary.
0.82 - 1.36	25 - 41	A/Btj1		CLAY LOAM; very dark grayish brown and dark reddish brown (10YR 3/2 and 7.5YR 3/2) when dry, very dark brown (10YR 2/2) when moist; moderate medium subangular blocky structure; hard when dry, firm to very firm when moist, sticky and plastic to very plastic when wet; many thin clay coatings on clast pockets; common rootlets; scattered fragments of charcoal; with rip-up clasts of siltstone; common fine subrounded gravel and coarse sand; abrupt and wavy boundary.
1.36 – 2.13	41 – 65	Btj2		CLAY LOAM to CLAY; yellowish brown (10YR 5/4) when dry, very dark brown grayish brown (10YR 3/2) when moist; moderate coarse angular blocky structure; very hard to extremely hard when dry, extremely firm when moist, very sticky and plastic to very plastic when wet; continuous moderately thick very dark grayish brown to very dark brown (10YR 3/2 and 2/2) clay films in pores; common rootlets; many fine to very

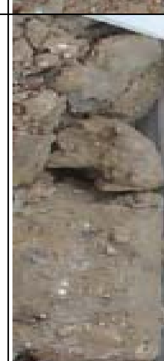
				fine pinhole pores; few rounded to subrounded gravel; abrupt to clear and wavy boundary.
2.13 – 2.89	65 – 88	2Ab1/2Bt1b		CLAY; very dark grayish brown (10YR 3/2) when dry, very dark brown (10YR 2/2) when moist; moderate medium angular blocky breaking to moderate fine angular blocky structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; common thin clay stains; few fine manganese oxide stains and nodules; many very fine pinhole pores; common roots and rootlets; scattered subrounded gravel to 4-cm in diameter; abrupt and wavy boundary.
2.89 – 3.74	88 - 114	2Btb2		CLAY; dark brown and very dark brown (10YR 3/3 and 2/2) when dry, very dark brown (10YR 2/2) when moist; strong coarse angular blocky structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; many thin and common moderately thick clay films on ped faces, common moderately thick clay films in pores; many fine and medium-sized pinhole pores; scattered gravel to 1-2 cm in diameter, predominantly angular, more than horizon above; abrupt to clear and wavy boundary.
3.74 – 5.28	114 - 161	3Ab2		CLAY LOAM grading down to CLAY at depth; very dark grayish brown (10YR 2/2) when slightly moist and moist (no dry color available); moderate fine to medium angular blocky structure grading to moderate coarse angular blocky structure at depth, in lower bench; soft to slightly hard when slightly moist, friable when moist, sticky to very sticky and plastic when wet; many pinhole pores; abrupt and wavy boundary.
5.28 – 6.33	161 – 193	4Btb3		CLAY; very dark gray and dark brown (7.5YR 3/1 and 3/2) when dry, dark brown (7.5YR 3/2) when moist; strong medium to coarse angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; many moderately thick clay films on ped faces, continuous moderately thick clay films in pores, many to continuous moderately thick clay films bridging grains; many rootlets; many subangular to subrounded gravel; clear and wavy boundary.

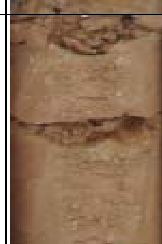
6.33 – 7.55	193 – 230	4Btb4		CLAY; very dark gray and dark brown (7.5YR 3/1 and 3/2) when dry, dark brown (7.5YR 3/2) when moist; strong very coarse angular blocky breaking to strong medium prismatic structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; many thin to moderately thick clay films on ped faces, many moderately thick clay films in pores and bridging grains; many fine gravel; clear and wavy boundary.
7.55 – 8.53	230 – 260	4Btb5		CLAY; dark brown (7.5YR 3/3) when dry, dark brown (10YR 3/3) when moist; strong coarse to very coarse angular blocky to prismatic structure; soft to slightly hard when dry, friable when moist, sticky and plastic when wet; many moderately thick very dark grayish brown (7.5YR 3/2) clay films on ped faces and bridging grains, continuous moderately thick to thick clay films in pores; few pinhole pores; common coarse sand and very fine gravel; less clay than horizon above; abrupt to clear and wavy boundary.
8.53 – 9.74	260 – 297	4BCb1		SANDY CLAY LOAM; brown and dark brown (7.5YR 4/4 and 3/2) when slightly moist, dark brown (7.5YR 3/2.5) when moist; moderate coarse angular blocky to prismatic breaking to strong medium angular blocky structure; soft to slightly hard when dry, friable when moist, sticky and slightly plastic when wet; common moderately thick and many thin clay films on ped faces, many thin clay films in pores, common to many thin clay coatings on clasts, many thin to moderately thick clay films bridging grains; with subangular to subrounded gravel; many pores; clear and wavy boundary.
9.74 – 10.33	297 – 315	4BCb2		SILTY CLAY LOAM to SILTY CLAY; strong brown (7.5YR 4/6) when dry, dark brown (7.5YR 3/3) when moist; moderate medium angular blocky structure; soft to slightly hard when dry, friable when moist, sticky and plastic to very plastic when wet; few to common thin dark brown (7.5YR 3/2.5 when moist) clay films on ped faces; common pores; clear and wavy boundary with a stoneline at the contact. Charcoal sample collected from this horizon.
10.33 – 12.04	315 – 367	4Cb1		Fine SANDY CLAY grading to SANDY CLAY LOAM at bottom; dark brown (10YR-7.5YR ¾) when slightly moist, dark brown (10YR-7.5YR 3/3) when moist; moderate medium angular blocky structure; friable when moist, sticky and plastic when wet; common thin clay films in pores and as stains; few pinhole pores; scattered coarse sand and fine gravel; clear to gradual and wavy boundary.

12.04 – 12.63	367 - 385	4Cb2		SANDY CLAY LOAM; brown to dark yellowish brown (7.5YR-10YR 4/4) when slightly moist, dark brown (7.5YR-10YR 3/3) when moist; weak to moderate fine subangular blocky structure; friable when moist, sticky and slightly plastic to plastic when wet; few clay stains; common pinhole pores, few rootlets; scattered gravel, less than horizon above; clear and wavy boundary.
12.63 – 13.02	385 – 397	5Cb3		SAND with gravel and cobbles to 8-cm in diameter, especially at bottom; yellowish brown (10YR 5/4) when dry, very dark to dark grayish brown (10YR 3.5/2) when moist; single-grained; loose when dry and moist, non-sticky and non-plastic when wet; clasts are subangular to subrounded; abrupt and wavy boundary.
13.02 – 14.34	397 – 437+	6Cb4		Gravelly fine to medium SAND coarsening upward to Fine SANDY LOAM; dark yellowish brown (10YR ¾) when slightly moist, dark brown (10YR 3/3) when dry; single-grained and weak medium to coarse angular blocky structure; loose to soft when dry, loose to very friable when moist, non-sticky and non-plastic when wet; abundant roots; OSL and charcoal sample collected from this unit; abrupt and smooth boundary to a mudflow deposit exposed to the east of soil profile. Charcoal and OSL samples collected from this unit.

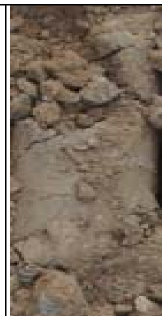
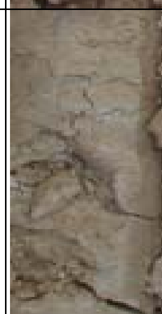
Profile No. 4 – Leighton's Boring CB-3

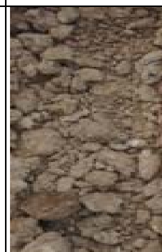
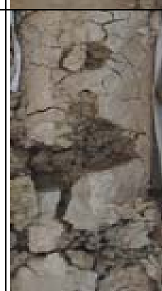
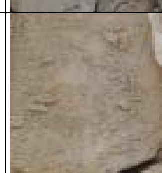
Depth (ft)	Depth (cm)	Horizon Designation		Description
0 – 2	0 – 61	NA		Not available for review. Refer to Leighton's log for details, based on cuttings.
2 – 3.6	61 – 109	Bt1		Gravelly CLAY, clay content decreases downward; very dark grayish brown (10YR 3/2) and brown (7.5YR 4/4) when moist; common moderately thick clay films bridging grains, common moderately thick and many thin clay films on ped faces; fine subrounded gravel, with clasts of slate and quartz.

4.6 - 5	109 – 152	Bt2-Bt_{lam}		Gravelly SANDY CLAY LOAM with Bt lamellae, especially in the lower section, below 3.9 ft; light brownish gray (10YR 6/2) when dry, brown (10YR 3.5/3) when moist, clay in lamellae is yellowish red (5YR 5/6) when dry, brown (7.5YR 4/4) when moist; friable when moist. [Section between 5 and 5.3' missing].
5.4 – 8.7	165 – 264	2Bt3		CLAYEY GRAVEL (gravel surrounded by pedogenic clay); mixed colors that reflect the mixture of slate, basalt and granitic clasts, with zones associated with weathered clasts that are grayish brown (2.5Y 5/2) when dry, dark gray (2.5Y 4/1) when moist; clay is reddish brown (5YR 4/4) when dry, brown (7.5YR 3.5/4), when moist; friable when moist; predominantly angular gravel.
8.7 - 10	264 – 305	3Bt4		SANDY CLAY; reddish brown (5YR 4/4) when dry, reddish brown (7.5YR 3.5/4) when moist; moderate fine to medium angular blocky soil structure; common thin clay films bridging grains; more clay and less gravel than horizon above.
10 – 15.5	356 – 472	4BC1/Bt_{lam}		SILTY CLAY with SANDY CLAY Bt lamellae zones; silty clay is light olive brown (2.5Y5/3) when dry, dark olive brown (2.5Y3.5/3) when moist; lamellae are brown (7.5YR 4/4) when dry, dark brown (7.5YR 3/4) when moist, with mottles that are reddish brown (5YR 4/3) when dry and dark reddish brown (5YR 3/3) when moist; locally, in the lamellae, common thin clay films bridging grains; abundant gravel, especially at the top of the horizon.
15.5 – 16.7	472 - 508	5Bt5		SILTY CLAY to CLAY with sand; strong brown (7.5YR 4/6) when dry, brown (7.5YR 4/4) when moist; very sticky and very plastic when wet; few thin (1/4-inch) zones with less clay and grayer in color.

16.7 – 17.3	508 - 528	5Bt6		SILTY CLAY to very fine SANDY CLAY; dark yellowish brown (10YR 4/4) with brown (7.5YR 4/4) mottles when dry, dark yellowish brown (10YR 3.5/4) with brown (7.5YR 4/4) mottles when moist; very sticky and plastic to very plastic when wet; common thin clay films on ped faces, common to many moderately thick clay films bridging grains.
17.3 – 19.6	528 – 597	5Bt7		Fine SANDY CLAY to CLAY; dark yellowish brown (10YR 4/4) with brown (7.5YR 4/3) mottles when dry, dark yellowish brown (10YR 3/4) with brown (7.5YR 4/4) mottles when moist; very sticky and plastic to very plastic when wet; common moderately thick clay films bridging grains.
19.6 – 21.2	597 – 645	6Bt8		Gravelly SANDY CLAY; dark yellowish brown to brown (10YR to 7.5YR 4/4) when dry, dark yellowish brown to dark brown (10YR to 7.5YR 3/4) when moist; sticky to very sticky and plastic when wet; common to many moderately thick dark brown (7.5YR 3/3) clay films on ped faces, many moderately thick clay films bridging grains.
21.2 – 21.9	645 – 668	6BC2/Bt$_{lam}$		Gravelly fine to coarse SAND; dark yellowish brown and dark grayish brown (10YR 4/4 and 4/2) when dry, dark yellowish brown to dark brown (10YR to 7.5YR 3/4); single-grained; with LOAMY SAND to SANDY LOAM Bt lamellae which are dark brown (7.5YR 3/4) when dry, brown (7.5YR 4/4) with yellowish red (5YR 4/6) mottles when moist; lamellae have weak to moderate fine angular blocky soil structure.
21.9 – 22.7	668 – 691	7Bt9		SANDY CLAY; dark yellowish brown (10YR4/4) with brown (7.5YR4/4) clay when dry and dark yellowish brown (10YR3.5/4) with strong brown (7.5YR4/6) clay when moist; sticky to very sticky and slightly plastic to plastic when wet; few thin clay films on ped faces and many thin clay films bridging grains.
22.7 – 23.7	691 – 721	7C1$_{lam}$		Fine SANDY CLAY with Bt lamellae; light brownish gray (2.5Y 6.5/2) when dry, grayish brown (2.5Y4.5/2) when moist; Bt lamellae are reddish yellow (7.5YR 6.5/6) when dry, brown (7.5YR 4/4) when moist; lamellae increase downward, appear to be controlled by primary sedimentary structure.

23.7 – 24.2	721 – 737	7C2		SANDY CLAY LOAM; dark yellowish brown (10YR 4/4) when slightly moist, dark yellowish brown (10YR 3.5/4) when moist; sticky and slightly plastic when wet; primary sedimentary structures visible.
24.2 – 27.6	737 – 841	8Bt10		CLAY; dark brown (7.5YR 3/3) with yellowish red (5YR 5/6) mottles when dry, dark yellowish brown to brown (10YR to 7.5YR 4/4) when moist; extremely hard at the top to very hard at the bottom when dry, very sticky and very plastic when wet; many thin and common moderately thick clay films on ped faces, many moderately thick clay films bridging grains.
27.6 – 29.1	841 – 886	9Bt11		CLAY; dark yellowish brown and gray (10YR 4/4 and 10YR 6/1) when dry, brown (7.5YR 4/3) when moist; moderate coarse angular blocky soil structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; continuous moderately thick clay films in pores, many moderately thick clay films on ped faces.
29.1 – 30.9	886 - 942	9Bt12		SANDY CLAY to CLAY with scattered gravel; brown (7.5YR 5/4) when dry, dark brown (7.5YR 3.5/4) when moist; strong coarse angular blocky grading to moderate medium to coarse subangular blocky soil structure; sticky and plastic when wet; common thin brown (7.5YR 4/3) clay films on ped faces, many moderately thick clay films bridging grains.
30.9 – 34.4	942 – 1049	10BC3		Gravelly SANDY CLAY LOAM; yellowish brown (10YR 5/4) with dark yellowish brown (10YR 4/4) clay stains when dry, dark yellowish brown (10YR 4/4) when moist; very hard when dry, friable when moist, sticky and slightly plastic to plastic when wet; common moderately thick clay films bridging grains, many moderately thick clay films in clast pockets.
34.4 – 35	1049 – 1067	11Bt13		Gravelly CLAY; dark yellowish brown (10YR 4/4) when dry, dark brown (10YR 3/4) when moist; very hard when dry, very firm when moist, sticky and plastic to very plastic when wet; many moderately thick clay films bridging grains, common thin clay films on ped faces.

35 – 36.8	1067 – 1123	11BC4		SANDY CLAY LOAM; dark yellowish brown and light gray (10YR 4/4 and 2.5Y 7/2) with strong brown (7.5YR 5/6) mottles when dry, dark yellowish brown and gray (10YR 3/4 and 2.5Y 5/1) with strong brown (7.5YR 4/6) mottles when moist; hard when dry, friable to very friable when moist, sticky and non-plastic to slightly plastic when wet; few to common thin clay films on ped faces, many to continuous moderately thick clay films bridging grains.
36.8 – 38.2	1123 – 1163	12Bt14		SILTY CLAY to CLAY; brown and dark brown (7.5YR 4/3 and 3/3) when slightly moist, brown (7.5YR 3.5/3) when moist; strong coarse angular blocky soil structure; very sticky and plastic to very plastic when wet; many to continuous moderately thick clay films bridging grains, common moderately thick and many thin clay films on ped faces; stone line at base of horizon.
38.2 – 52.5	1163 – 1600	13C3$_{lam}$		SILT; yellowish brown and light brownish gray (10YR 5/6 and 2.5Y 6/2) when dry, gray and yellowish brown (2.5Y 5/1 and 10YR 5/4) when moist; very sticky and slightly plastic when wet; primary sedimentary structures still visible; locally with Bt lamellae and zones at 477-480", 497-501", 509-511", 522-527", 608-610", and 620-625"; zones are brown (7.5YR 5/4) when dry, dark brown (7.5YR 3/3) when moist; sand lenses at 530 to 532" and 576 to 578".
52.5 – 55.5	1600 – 1692	14Bt15		CLAY with visible sand grains; dark brown (10YR 3/3) when slightly moist, dark brown (7.5YR 3/3) when moist; strong coarse angular blocky breaking to strong fine angular blocky soil structure; very hard to extremely hard when dry, very firm to extremely firm when moist, very sticky and very plastic when wet; many moderately thick clay films bridging grains, common to many moderately thick clay films on ped faces at the top grading to many to continuous moderately thick clay films on ped faces at the bottom; few scattered calcium carbonate nodules; grayer zones seem to be grussified clasts.
55.5 – 57.25	1692 – 1745	14Bt16		CLAY; brown (10YR 5.5/3) with few yellowish red (5YR 5/6) mottles when dry, brown (10YR 4/3) when moist; very sticky and very plastic when wet; few moderately thick and common thin clay films on ped faces, common moderately thick clay films bridging grains.
57.25 – 67.2	1745 – 2047	14BC5		SILTY CLAY to CLAY; light yellowish brown and light gray (10YR 6/4 and 2.5Y 7/2) when dry, yellowish brown and light olive brown (10YR 5/4 and 2.5Y 5/3) when moist; weak to moderate coarse angular blocky soil structure grading to massive at bottom; very hard to extremely hard when dry, extremely firm when

				moist, very sticky and plastic to very plastic when wet; silt at 65 feet (780").
67.2 – 68.75	2047 – 2096	15Bt17		CLAY; brown (10YR 5/3) when dry, brown (10YR 4/3) when moist; moderate medium angular blocky to strong fine angular blocky soil structure; very sticky and very plastic when wet; many thin and common moderately thick dark yellowish brown (10YR 4/4) clay films bridging grains; few manganese oxide stains.
68.75 – 71	2096 – 2164	15Bt18		CLAY; olive brown and brown (2.5Y 4/3 and 10YR 4/3) with brown (7.5YR 4/4) mottles when dry, dark yellowish brown (10YR 3.5/3) with dark brown (7.5YR 3.5/4) mottles when moist; moderate to strong coarse angular blocky soil structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; pockets of sand visible locally.
71 – 72.5	2164 – 2210	15Bt19		CLAY; very dark grayish brown (2.5Y-10YR 3/2) with few fine brown (7.5YR 4/4) mottles when slightly moist; strong fine angular blocky soil structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; many moderately thick to thick clay films on ped faces, many to continuous moderately thick clay films bridging grains.
72.5 – 73.25	2210 – 2233	15C4		Fine SAND; light yellowish brown (10YR 6/4) and light gray (2.5Y 7/2) when moist; massive breaking to single-grained; very friable when moist, non-sticky and non-plastic when wet.
73.25 – 74.4	2233 – 2268	16Bt20		SILTY CLAY; dark grayish brown (2.5Y 4.5/2) with common fine brown (7.5YR 5/4) mottles when dry, dark gray (2.5Y 4.5/1) with brown (7.5YR 4/4) mottles when moist; strong coarse angular blocky soil structure; very sticky and plastic when wet.
74.4 – 75	2268 – 2286	16Btk		SILTY CLAY; light brownish gray (2.5Y 6/2) with reddish yellow (7.5YR 6/4) mottles when dry; very sticky and plastic to very plastic when wet; common fine to medium calcium carbonate nodules and stringers.
75 – 75.2	2286 – 2291	16BC6		SAND with few scattered fine calcium carbonate nodules.

75.2 – 79.6	2291 - 2426	16BC7		CLAY; gray and dark gray (2.5Y 5/1 and 2.5Y 4/1) with brownish yellow (10YR 6/8) mottles when dry; strong fine angular blocky soil structure; many to continuous moderately thick clay films bridging grains.
79.6 – 80	2426 – 2438	17C5		SANDY CLAY; light brownish gray (2.5Y 6/2) when dry, light olive brown (2.5Y 5/3) when moist; very hard to extremely hard when dry, friable when moist, slightly sticky and plastic when wet; cemented. Section between 80-80.5’ (2438-2454 cm) was missing.
80.5+	2454+	18C6		SAND; light gray (2.5Y 7/2) when dry, light olive gray (5Y 6/2) when moist; single-grained; (San Pedro Formation).

December 21, 2012 (updated)
ECI Project No. 3205.02

Earth Consultants International

To: **Hill Farrer & Burrill, LLP**
300 South Grand Avenue, 37th Floor
Los Angeles, California 90071-3147
Attention: **Mr. Kevin Brogan, Partner**

To: **Leighton Consulting, Inc.**
17781 Cowan
Irvine, California 92614
Attention: **Mr. Joe Roe, Sr. Project Geologist**

Subject: **Supplemental Report on the Age of the Sediments Underlying the Beverly Hills High School and Vicinity Using Soil-Stratigraphic Techniques, 241 Moreno Drive, Beverly Hills, California**

Dear Mr. Brogan and Mr. Roe,

At the request of Tim Buresh of PrimeSource Consulting, Earth Consultants International (ECI) provided Leighton Consulting, Inc. (Leighton) with support in the analysis and interpretation of the faulting exposed in trench FT-5, and with the age of the sediments exposed therein and in nearby locations. This letter report summarizes our findings regarding the age of the sediments exposed in the area of trench FT-5, and our assessment of the age of the sediments we examined previously (Earth Consultants, April 2012) based on the findings presented herein. Our opinions regarding the age of the faults exposed in trench FT-5 have been provided in several field and office meetings with personnel from Leighton, the California Geological Survey, Kenney GeoScience, and PrimeSource Consulting. The results of this study add to the body of geological data that has been developed for this area of the Cheviot Hills as a result of several fault investigations conducted at and near the Beverly Hills High School (Leighton, 2012; Kenney GeoScience, 2012; Geocon & Feffer, 2012).

Prior to the excavation of trench FT-5, we reviewed and described the soils and sediments in the uppermost 40 feet of the cores collected from borings B-23, B-24 and B-26. These borings were emplaced by Leighton in the area where trench FT-5 was later excavated. The cores were reviewed to provide an opinion as to whether or not the near-surface deposits present along the transect covered by the borings were similar, which would in turn provide information regarding the lateral continuity of the sediments and the potential for a fault to extend across the area. Upon review of the cores, it was our opinion that there were noticeable differences in the near-surface sediments recovered in the borings, as later confirmed upon excavation of the trench. Our descriptions of the upper sections of the cores are included in this report. Age estimates for the soils developed within these sections were calculated and are also provided here.

Trench FT-5 was emplaced in a northerly direction starting near the base of, and extending away from the slope at the northern end of the school, across the area where Fault F2 had been proposed (Kenney GeoScience, 2012, Plate ES-2b). The trench exposed Pleistocene-age sediments consisting of fluvial gravels and sands near its southern end, and finer-grained silts and clays at its northern end. The soil profile that we described was from the area of the trench where finer-grained sediments predominated. The soils described in that section of the trench indicate an estimated age of nearly 150,000 years for the uppermost 3.5 meters (11.5 feet). This age estimate is based only on the properties of the soils exposed in that section of the trench. Together with Leighton, we made an effort to correlate the sediments exposed in their trench FT-5 with the soils exposed in the trench excavated in the property to the north, the 10000 Santa Monica Boulevard site (Geocon & Feffer, 2012). If the correlations are correct, the fine-grained sediments near the top of the FT-5 trench, which at this location did not exhibit any soil development, are about 60,000 years old, making the entire section (to a depth of 3.5 meters) at least 210,000 years old. The 60,000-year age for the uppermost sediments is also consistent with the Infra-Red Stimulated Luminescence (IRSL) dating results obtained independently by Dr. Rhodes (2012b). These correlations are discussed further in the body of this report.

Based on the soils that we described in the three cores that were part of this study, the sediments in the southern part of the study area are at least 100,000 years old, whereas the sediments in the northernmost portion of the study area are about 30,000 years old. Both of these age estimates are minimum values, as these ages do not include any periods of time bracketing the stable periods of soil formation when depositional and erosional processes dominated. Furthermore, and significantly, a qualitative comparison of the soils exposed in core CB-26 and in trench FT-5 strongly suggests that the drilling process destroys some of the soil characteristics used in the age estimations, resulting in lower age values. As a result, the age estimates calculated from the cores should be used with caution. This finding most likely also applies to the soil-age estimates we made earlier from boring CB-3 (Earth Consultants, April 2012).

An effort was made to discern whether the sediments exposed in the borings and trench are consistent with and thus can be assigned to either the Cheviot Hills deposits (CHD) or Benedict Canyon Wash deposits (BCWD) of Kenney GeoScience (2012). Dr. Kenney assigned the fluvial gravels and sands observed at the top of the section near the southern end of the trench to the Benedict Canyon Wash deposits; in our opinion that is a viable interpretation. A review of the two borings to the north (CB-23 and CB-24) indicates that gravelly deposits that could represent the bottom of the Benedict Canyon Wash were observed at a depth of 20.75 feet (6.3 meters) in boring CB-23 and a depth of 36.5 feet (11.1 meters) in boring CB-24. Those depths correlate closely with Dr. Kenney's proposed bottom for the Benedict Canyon Wash. However, the finer-grained sediments both above and below these gravelly deposits are similar in texture, color and other characteristics, making it difficult to obtain a more definite determination of the contact between the Cheviot Hills and Benedict Canyon Wash deposits. That these deposits are very similar throughout also suggests that the source for these sediments has not changed in hundreds of thousands of years.

Thank you for the opportunity to assist the Beverly Hills School District and your firms with this study. Should you have any questions regarding our attached report, please do not hesitate to contact the undersigned.

Respectfully submitted for
Earth Consultants International, Inc.

Tania Gonzalez, CEG 1859
Vice-President
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Earth Consultants International

Supplemental Soil-Stratigraphic Studies to Estimate the Age of the Sediments Underlying the Beverly Hills High School Campus

BACKGROUND and METHODOLOGY

Soil-stratigraphic studies have been conducted previously at the campus of the Beverly Hills High School (BHHS) by this firm (Earth Consultants International, April 2012). Please refer to our previous report for a more thorough discussion on the background of soil age estimation and the methodology that we employed. As with our previous study, we described the soil profiles according to the characteristics and nomenclature established by the Soil Survey Staff (1975, 1992) and Birkeland (1984, 1999). Dry and moist colors of the samples were recorded using a Munsell Soil Color Chart.

Soil development index (SDI) values were calculated for the soil profiles observed based on the field descriptions using a modified version of the Harden (1982) index, and the maximum horizon index (MHI) of Ponti (1985). Soil properties used in the analyses include texture, color, structure, consistency, and presence of clay films or clay coatings. Both SDI and MHI values are considered useful relative indicators of age when comparing soils developed in similar parent materials under similar climatic conditions (Bornyasz and Rockwell, 1997; Rockwell et al., 1990; Rockwell et al., 1984; Harden, 1982). Minimum age estimates for the deposits were made by comparing the SDI and MHI values obtained for the soils described with those of dated soils developed in the southern California region under similar climatic and parent material conditions (Dolan et al., 1997; Dolan et al., 2000, and the soil age regressions referenced therein).

To calculate the SDI and MHI values for this study we used a parent material consisting of loamy sand, light gray (10YR 7/2) when dry, pale brown (10YR 6/3) when moist, single-grained, loose when dry and moist, non-sticky and non-plastic when wet. This assumed parent material is sandier and lighter-colored than the parent material that we used for the soil-age estimations presented in our April 2012 report, which consisted of a sandy loam, dark brown (10YR 3/3) when moist, dark yellowish brown (10YR 4/4) when dry, single-grained, loose to soft when dry, loose to very friable when moist, non-sticky and non-plastic when wet. The parent material used in our earlier report was based on a sedimentary bed observed near the bottom of trench FT-2. The parent material used in this study is intermediate between the "raw" alluvium (consisting of sand with 2.5Y and 10YR hues) used by Helms (Geocon & Feffer, 2012) for the soil-age estimations in the 10000 site, and the parent material we used earlier. The result of using this revised parent material is a slight increase in the estimated ages presented in our earlier report.

SCOPE OF WORK

For this study we were tasked with reviewing and describing the near-surface sediments in three borings and one trench emplaced near the northeastern corner of the BHHS campus. The core descriptions were made before trench FT-5 was excavated, and from that review we were to provide an opinion as to whether or not similar sediments were likely to be exposed along the length of the trench. This in turn would provide data on whether or not the uppermost (i.e., most recent) sediments extend unbroken across this portion of the school campus (a laterally discontinuous package could suggest faulting and/or channeling, for example). Given that the borehole data indicated that the top of the San Pedro sediments is vertically offset through this area, a review of the uppermost section would provide data on whether or not this break or step in the stratigraphy extends upwards to shallow depth, within the area and at the depth that was to be exposed by trenching.

The soil profiles described are summarized as follows:

1. Profile 1: On the east wall of Trench FT-5 at station 0+81.

2. Profile 2: Upper 40 feet of Boring CB-23, which was emplaced about half-way through the study area, in the immediate vicinity of Station 0+65 of Trench FT-5.

3. Profile 3: Upper 40 feet of Boring CB-24, which was emplaced at the north end of the study area, in the immediate vicinity of Station 1+10 of trench FT-5.

4. Profile 4: Upper 40 feet of Boring CB-26, which was emplaced at the south end of the study area, in the immediate vicinity of Station 0+00 of trench FT-5.

Summarized soil descriptions for these profiles are provided in Tables 1 through 4. The complete soil descriptions for each of these profiles are included as Appendix A.

As an addendum to this study, we also reviewed the soil-age estimations made by John Helms for the Geocon West/Feffer Geological Consulting team that studied the fault rupture hazard at the 10000 Santa Monica Boulevard site (the "10000 site") north of the BHHS campus (Geocon & Feffer, 2012). Specifically, we were asked to correlate, if possible, the sediments and soils described in their trench with the sediments and soils described in trench FT-5, and use the age estimates from the 10000 site study to develop a more thorough understanding of the stratigraphic history of the sediments underlying this part of the Cheviot Hills. To that end, we reviewed the soil development indices developed by Mr. Holmes, and compared his soil descriptions to those that we made from borings and trench exposures at BHHS. Together with Leighton's personnel, we also compared the geological descriptions of the units described in the 10000 site with the units described in trench FT-5, in an effort to correlate the geological units across the area between the two exposures. The correlations made, including age estimates for these units, are discussed further below.

FINDINGS

The sediments described in all four profiles are terrestrial materials consisting primarily of alluvial fan, fluvial and mudflow deposits. Notable differences in the amount and extent of soil formation were observed among the profiles described. Specifically, significant soil development was observed in the core of boring CB-26, at the south end of the study area. Four separate soils were identified in the upper 9.14 meters (30 feet) of this core, indicating at least four separate periods of stability when soil-forming processes dominated. The uppermost soil has an A/Bt1/Bt2 profile, colors in the 7.5YR hue, and many moderately thick clay films in pores and bridging grains. The argillic horizons have a combined thickness of 95 cm (3.12 feet). The next soil down has an A/Btj/C1/C2 profile, 7.5YR hues in the A/Btj/C1 horizons, and few to common thin clay films on ped faces and bridging grains. This soil was exposed to soil-forming processes for a relatively short period of time or its upper horizons were removed by erosion before the overlying sediment was deposited. The third deeper soil is well developed, with a Bt1/B2/Bt3/BC/Cl_{am} profile, 7.5YR hues in the argillic horizons, and common to many moderately thick clay films on ped faces, bridging grains, and in pores. The three argillic (Bt) horizons combined have a thickness of 135 cm (4.43 feet), which could indicate wet climatic conditions during their formation. The deepest soil observed and described has a Bt/C_{lam}1/C_{lam}2 soil profile, 7.5YR hues in the argillic horizon, and few to many thin clay films on ped faces, in pores, and bridging grains. The argillic horizon is only 33 cm (1.08 feet) thick, whereas the underlying C_{lam} horizons have a combined thickness of 221 cm (7.25 feet). This strongly suggests that the uppermost section of this soil was removed by erosion before deposition of the overlying sediment.

In contrast, the core of boring CB-24, at the north end of the study area, displays only minor soil development in a profile dominated by primary sedimentary characteristics. Furthermore, the deposits modified by soil development are both overlain and underlain by sediments not altered by pedogenesis. The sediments comprising this core are typically laminated to thinly bedded, and color banded (variously described as "varved" or "tiger striped"). Two soils were identified in this profile, with the first soil occurring at a depth of between 2.36 and 3.63 meters (7.75 and 11.92 feet), and the second between 3.63 and 5.69 meters (11.92 and 18.67 feet) depth. Both soils display juvenile argillic horizons (Btj) underlain by C horizons. Few thin clay films on ped faces were observed only in the juvenile argillic horizon of the deeper soil.

The core of boring CB-23 was disturbed during the drilling process, exhibiting concentric rings of material of different textures and colors that were evident when the core was broken both longitudinally and in cross-section so as to expose the materials inside. The descriptions of the soils and sediments from that core should therefore be used with caution. Nevertheless, the descriptions do suggest that, as with the core of boring CB-24, most of the materials exhibit primary sedimentary characteristics, with pedogenic development observed only in two portions of the 12.2-m- (40-foot-) thick section. The first of these soils was observed near the surface, at a depth of between 0.66 and 2.64 meters (2.16 and 8.66 feet), although the soil may extend deeper as no core was recovered for the section between 2.64 and 3.05 meters (8.66 and 10 feet). This moderately well-developed soil has an AB/Bt1/Bt2/Bt3 profile, 7.5YR and 10YR hues, and many thin to moderately thick clay films on ped faces, on clasts, and bridging grains in the upper argillic horizon. The argillic horizons have a combined thickness of at least 112 cm (3.7 feet). The second soil described was deeper in the core, at a depth of 9.14 to 12.19 meters (30 to 40 feet). This soil is unusual and unlike the other soils described for this study in that its A1/A2 soil horizons appear to have been burned, as suggested by localized black stains, and because the soil clasts from these horizons do not weigh as much as expected for their size. Structures reminiscent of worm casts were observed in the A2/Bt1 horizon. The combined thickness of the argillic horizons is 71 cm (2.3 feet). Other characteristics include 10YR color hues, moderate to strong angular blocky structure, and common to many thin clay films on ped faces, and many moderately thick clay films in pores and bridging grains.

Finally, the profile described at Station 0+81 in trench FT-5 showed thin layers of non-altered sediment overlying a pedogenically altered section containing three soils. The sedimentary package overlying the uppermost soil increased in thickness toward the north, consistent with the observations made in boring CB-24. The first soil described in this part of the trench has a well-developed soil with an A/Bt1/Bt2/BC profile, 10YR to 7.5YR hues and 2.5Y gleying. The better developed Bt2 horizon has strong fine to moderate prismatic structure breaking to strong angular blocky structure, and many thick to common moderately thick clay films on ped faces and continuous moderately thick clay films bridging grains.

The second soil described is truncated as evidenced by the lack of an A soil horizon and a thin argillic horizon. Colors in this soil range from 2.5Y to 7.5YR. The argillic horizon has many moderately thick clay films bridging grains, and continuous thin and many moderately thick clay films on ped faces. The third and deepest soil observed and described in the trench has a relatively thin argillic horizon underlain by three BC horizons. This deeper soil has 10YR and 7.5YR hues with 2.5Y and 5Y gleying, weak to moderate fine subangular blocky structure, and common to many moderately thick clay films on ped faces in pores, and bridging grains.

AGE ESTIMATES

As we discussed in our April 10, 2012 report, soil age estimates do not provide an absolute age for the sediments; they only provide an estimate of the amount of time that a soil was exposed to soil-forming processes at or near the ground surface. The estimates are also typically minimum values given that erosion often removes the uppermost section of a soil before it gets buried by sediment. This was observed in several of the soils described for this study, wherein the topsoil (A horizon) and part of the argillic (Bt) soil horizons were not present. The lack of these uppermost horizons limits the age estimates obtained using the Soil Development Index (SDI) method, as this method adds up the values calculated for each horizon, taking into consideration the total thickness of the horizon, to arrive at a total soil development index value. For this reason, for the truncated soils we have given preference to the age estimates developed using the Mean Horizon Index (MHI) method, which is based on the characteristics of the best developed horizon within a soil, and is also independent of the thickness of the horizon. The MHI and SDI values calculated for the soils described are provided in the two far-right columns in Tables 1 through 4, and on Table 5. For a summary of the age estimates discussed below, refer to Table 5.

The topmost 12.2 m (40-foot) section of boring CB-26 at the south end of the study area has four stacked soils. The first, third and fourth soils (Soils 1, 3 and 4) in that profile are moderately well-developed, with MHI values around 0.45. The first and third soils are each estimated to have been exposed to soil-forming processes for about 30,000 years, whereas the fourth soil is estimated to have developed over a period of about 26,000 years (median values). Soil 2 in this profile has characteristics that indicate a shorter exposure to soil-forming processes, with estimated ages of about 12,000. Combining all four soils together yields an estimated minimum age for the sediments of nearly 100,000 years.

Three soils were described in the profile exposed near Station 0+81 in trench FT-5. The two deeper soils (Soils 2 and 3) were truncated, as evidenced by a lack of topsoils (A horizons) and by thin argillic horizons. Soil 2 in particular has an overall thickness of 40 cm (1.3 feet), with an argillic horizon only 26 cm (0.85 foot) thick. However, the preserved soil sections show characteristics consistent with strong soil development, including many to continuous clay films and prismatic soil structure. MHI values we calculated for these soils range from 0.48 (Soil 2) to 0.61 (Soil 3). The first soil (Soil 1) in the profile is estimated to have a median age of about 47,000 years; Soil 2 about 33,000 years, and Soil 3, 68,500 years. The combined age of the stacked soils is 148,500 years using the MHI method (preferred), and 41,500 years using the SDI method.

As mentioned above, the core of boring CB-23 appeared disturbed and is thus believed to be less reliable. This boring, which was emplaced between the two profiles described above (CB-26 and FT-5), includes two soils, one near the current ground surface, and one considerably deeper. Both soils preserve their A soil horizons and have strongly developed argillic horizons. Because the soils preserve their A horizons and are each about 200 cm (6.56 feet) thick, the age estimates obtained using the MHI method correlate closely with the age estimates calculated using the SDI method. The first soil (Soil 1) is estimated to have been exposed to soil-forming processes for 26,000 to 38,000 years, and the second, deeper soil (Soil 2), for about 34,000 to 47,000 years. Since the two soils are separated by 6.5 m (21.3 feet) of sediment, potentially significant additional time needs to have occurred between the two periods of soil formation. Thus, the combined age of 60,500-85,000 years is a minimum value, and not deemed representative of the age of the entire section. [The minimum and maximum age estimates that capture 95% of the data used to construct the regression used in the analysis are 19,000 and 245,000 years, respectively, using both the MHI and SDI age estimates. For additional information refer to Table 5.]

The boring emplaced at the north end of the study area (CB-24) displayed the least amount of soil development, with two relatively weak soils observed in the section between 2.36 and 5.69 meters (7.7 and 18.7 feet). Both soils have only incipient (juvenile) argillic soil horizons with none to few clay films. The first soil is estimated to have been exposed to soil-forming processes for 14,000 years, and the second soil for about 14,500 to 20,500 years. Thus, the combined estimates yield an age for the pedogenically altered section of about 29,000-34,500 years. Additional un-quantified age is assigned to the 12.2 m (40-foot) section given that unaltered sediments both cap and underlie the soils described above. Essentially, in the area where this boring was emplaced, depositional (and possibly erosional) processes have dominated, limiting the usefulness of soils for age estimation.

Visually, the soils and sediments observed in the core of boring CB-26 appear to be better developed and older than the sediments observed in the trench at Station 0+81, even though the age estimates, using the MHI values, indicate otherwise. This suggests that soil descriptions made from cores have limitations that can affect the final age results. Specifically, it is harder to discern and thus describe the soil structure and the quality and quantity of the clay films in a core as compared to a trench wall. Soil structure in particular seems to be compromised by the drilling process. Accordingly, we suggest that the age estimates obtained for the cores and presented above are about 30 to 35% lower than the values that we would have calculated for the same sections had the descriptions been made from a trench or exposure rather than a core.

Table 1: Abbreviated Soil Profile Descriptions - Profile FT-5

Horizon	Depth (cm)	Thickness (cm)	Texture	Color		Structure	Consistency				Clay Films	MHI	SDI
				Moist	Dry		Dry	Moist	Wet				
First Soil													
2Ab	55 - 62	7	fSC	10YR 3/3	10YR 4/3	m - 1fsbk	sh	fri	s	p	2-3npf	0.2773	1.9411
2Btb1	62 - 80	18	SC	10YR 3/3	10YR 3/2	2-3msbk	vh	vfi	s	p	2mk-3npf, 4mkbr	0.4854	8.7371
2Btb2	80 - 134	54	SC-C	2.5Y 3/2 & 7.5YR 3/4	2.5Y 3/2 & 7.5YR 4/6	3f-mpr - 3fabk	h	fi	s	p-vp	2k&3mkpf, 4mkbr	**0.5415**	29.2425
3BCb	134 - 147	13	SC	7.5YR 3/3	7.5YR 4/3 & 3/3	m - 2fsbk	vh	fi-vfi	s	p	1mk&2npf, 3nbr	0.4792	6.2302
													46.1509
Second Soil													
4Btb3	147 - 173	26	SC	2.5Y 3/2 & 7.5YR 4/4	10YR 3/2 & 7.5YR 4/4	2fpr	vh-eh	sfi	s	p	3mkbr, 4n&3mkpf	**0.4834**	12.5684
5BCb2	173 - 187	14	SC	7.5YR 3/3	7.5YR 4/4 & 2.5Y 4/2	m - 2fsbk	h	fi	s	p	2npf, 3nbr	0.4336	6.0697
													18.6381
Third Soil													
6Btb4	187-202	15	SC-C	10YR 3/3 & 2.5Y 3.5/2	7.5YR 3/3 & 3/2	2fpr - 2fsbk	vh	fi	s	p	2mk&3npf, 3mkbr	**0.6075**	9.1127
6BCb3	202 - 243	41	SCL	10YR 3/3 & 2.5Y 4/2	10YR 4/4 & 7.5YR 3/2	m - 1fsbk	so	fri	s	p	2mkpf, 2-3mkpo	0.3193	13.0933
6BCb4	243 - 256	13	SC-C	10YR 4/4 & 5Y 3.5/1	7.5YR 4/6 & 5Y 4/1	m - 1fmsbk	so	fri	s	p-vp	3mkpf&po, 2mk&3nbr	0.3679	4.7831
7BCb5	256 - 340+	84	SCL	10YR 3/3	10YR 3/3 & 7.5YR 3/3	sg-1msbk	lo-so	lo-vfri	ss-s	sp	1npf	0.226	18.9872
													45.9763

ABBREVIATIONS

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Table 2: Abbreviated Soil Profile Descriptions - Profile CB-23

Horizon	Depth (cm)	Thickness (cm)	Texture	Color		Structure	Consistency				Clay Films	MHI	SDI
				Moist	Dry		Dry	Moist	Wet				
First Soil													
AB	66-152	86	SiC	7.5YR 3.5/3	10YR 4.5/3	unk.	vh-eh	fri	vs	p-vp	none	0.3619	31.1202
Bt1	152-178	26	C	10YR 3/3	10YR 5/3 & 7.5YR 4/3	m - 3c-vcabk	eh	efi	s	p-vp	3n-mkpf, 3mkcl, 3nbr	**0.5016**	13.0407
Bt2	178-218	40	C	10YR 4/4	10YR 5/4	1f-mabk	h-vh	vfi	s	p	1npf, 3n-mkcl	0.4106	16.4225
Bt3	218-264	46	SC-C	10YR 3.5/4	10YR 5/4, 7.5YR 4/4 & 2.5Y 5/2	m	vh	vfi	s	p	2npf, 2-3nbr	0.3914	18.7851
													78.5858
											Normalized to 200 cm		**79.3685**
Second Soil													
9Ab1	914-925	11	SiC	2.5Y 4/2	2.5Y 5/2	3fabk	vh	vfi	vs	vp	2npf, 1-2ncl, 2-3npo	**0.5426**	5.9688
9Ab2/Btb1	925-940	15	C	10YR 4/2 & 7.5YR 3/3	10YR 4/2 & 7.5YR 4/3	3f-cabk	vh	vfi	vs	vp	2-4npf, 3nbr	0.4837	7.2562
9Btb2	940-996	56	C	10YR 4/3, 2.5Y 4/2 & 7.5YR 3/3	10YR 3/3, 2.5Y 4/2 & 7.5YR 3/3	2cabk	h-vh	fi	s	p	2n-mkpf, 3mkpo, 3mkbr	0.423	23.6887
9BCb1	1000-1219	219	C-SC	10YR 3/3 & 7.5YR 3/3	10YR 4.5/2, 7.5YR 5/6 & 4/4	3c-vcabk	vh-eh	vfi	s	p	2mkpf, 2npo, 3mkbr	0.4908	107.4874
													144.4011
											Normalized to 200 cm		**94.8292**

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Table 3: Abbreviated Soil Profile Descriptions - Profile CB-24

Horizon	Depth (cm)	Thickness (cm)	Texture	Color Moist	Color Dry	Structure	Consistency Dry	Consistency Moist	Consistency Wet		Clay Films	MHI	SDI
First Soil													
2Btj1	236-318	82	C	10YR 4/3 & 2.5Y 3.5/2	10YR 4/3, 2.5Y 4/1 & 2.5Y 3/2	m - 3c-vcabk	vh-eh	fri	s	p	none	0.3295	27.0187
3C2	318-363	45	SiC	7.5YR 4/4 & 2.5Y 4/2	7.5YR 5/4 & 2.5Y 6/2	3m-cabk					none	0.249	11.2031
													38.2218
Second Soil													
4Btj2	363-511	148	C	7.5YR 3.5/3 & 2.5Y 4/2	7.5YR 5/4 & 2.5Y 5/2	m - 2m-cabk	vh	sfi	s	p	1npf	**0.3259**	48.2293
5C3	511-569	58	gSCL	10YR 3/4 & 5Y4.5/2	10YR 5/4 & 5Y 5/2	m - 3m-cabk	h-vh	sfi	s	sp-p	none	0.2941	17.0594
													65.2887
											Normalized to 200 cm		**63.5239**

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Table 4: Abbreviated Soil Profile Descriptions - Profile CB-26

Horizon	Depth (cm)	Thickness (cm)	Texture	Color Moist	Color Dry	Structure	Consistency Dry	Consistency Moist	Consistency Wet		Clay Films	MHI	SDI
First Soil													
4Ab	241-263	34	SL	7.5YR 3/2	7.5YR 4/3.5	unk.		vfri-fri	s	p	1-2ncl, 1-2nbr	0.2956	10.0502
4Btb1	305-340	65	SC	7.5YR 4/4	7.5YR 5/3 & 6/2	3fabk	vh	fi	s-vs	p	2-3mkpf, 4mk-kcl, 3mkbr, 3mkpo	**0.4541**	29.5187
4Btb2	340-370	30	C-SiC	7.5YR 4/4 & 5Y 4.5/1	7.5YR 4/3 & 5Y 5/1	2-3fabk	h	fi	vs	p	3mkpo	0.417	12.5093
													52.0782
Second Soil													
5Ab/Btjb	370-399	29	LS-S	7.5YR 3.5/2	7.5YR 4/3	unk.	so	vfri	ns	np	1-2npf, 1-2nbr	0.1665	4.8296
5Cb1	399-442	43	fSC	7.5YR 4/3 & 5Y 3/2	7.5YR 5/4-4/4 & 5Y 5/2	m	vh	fi	s	p		0.2941	12.6475
5Cb2	442-475	33	fSC-SiC	10YR 4/4 & 2.5Y 5/2	10YR 5/4 & 2.5Y 5/2	m	vh-eh	vfi-efi	s	p		**0.2993**	9.8754
													27.3525
Third Soil													
6Btb3	475-533	58	C-SC	7.5YR 3/2.5	7.5YR 3/3 & 3/2	2m-cabk	sh	sfi	vs	vp	3-4mkpf, 2mkbr	0.4412	25.5912
6Btb4	533-554	21	C	7.5YR 3/3 & 2.5Y 4/2	7.5YR 3/2 & 4/4, 2.5Y 3/1	3m-cabk	vh	sfi	vs	vp	2mkpf, 3mkbr	**0.461**	9.6814
7Btb5	554-610	56	SiC	7.5YR 4/3.5 & 2.5Y 4/2	7.5YR 4/4 & 2.5Y 5/1	2cabk	vh-eh	fri	vs	vp	2ncl, 1-2npf, 3npo	0.4179	23.4016
8BCb1	610-625	15	fSC	10YR 4/3 & 7.5YR 4/4	10YR 4/4 & 7.5YR 4/4	1-2mabk	h	fri	s	p	1npf, 2-3nbr	0.3538	5.3064
8Clamb1	625-660	35	SiC	10YR 4/4 & 7.5YR 4/4	10YR 5/4 & 7.5YR 4/3.5	m-1cabk	so	fri	vs	vp	2npf	0.2991	10.4698
													74.4504
Fourth Soil													
9Btb6	660-693	33	fSC	7.5YR 4/3 & 2.5Y 3/2	7.5YR 4/3 & 2.5Y 4/1	1f-mabk		fri	s	p	1-2npf, 2-3npo	0.3406	11.2411
9Clamb2	693-851	158	SL-L	10YR 3.5/3 & 4/4	10YR 5/4 & 10-7.5YR 4/4	m-2f-mabk	so	fri	ss	np-sp	2-3npf, 2-3nbr	0.2749	43.4325
10Clamb3	851-914	63	C	10YR 3/4 & 7.5YR 3/3	10YR 4/4 & 7.5YR 3/2	m-2m-cabk	vh-eh	fi	s	p	2npf, 3n-mkcl	**0.4342**	27.3573
													82.0309
											Normalized to 200		**58.5818**

ABBREVIATIONS

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Table 5: Age Estimates for the Soils Described in this Study
(ages rounded to the nearest 500 years)

Soil	SDI	MHI	Average Age (years)	Minimum Age (years)	Maximum Age (years)
Profile FT-5-1					
Soil 1	46.15		15,500	5,000	48,500
		0.54	47,000	14,500	128,500
Soil 2	18.64		10,500	3,500	34,000
		0.48	33,000	10,500	105,000
Soil 3	45.98		15,500	5,000	48,500
		0.61	68,500	22,000	220,000
Totals for section (using SDIs)			41,500	13,500	131,000
Totals for section (using MHIs) **PREFERRED AGE ESTIMATES**			**148,500**	**47,000**	**453,500**
Profile CB-23					
Soil 1	79.37		26,500	8,000	83,000
		0.50	38,000	12,000	116,500
Soil 2	94.33		34,000	11,000	105,000
		0.54	47,000	14,500	128,500
Totals for section (using SDIs)			**60,500**	**19,000**	**188,000**
Totals for section (using MHIs)			**85,000**	**26,500**	**245,000**
Profile CB-24					
Soil 1	38.22		14,000	4,500	43,500
		0.33	14,500	4,500	46,000
Soil 2	63.52		20,500	6,500	64,000
		0.33	14,500	4,500	46,000
Totals for section (using SDIs)			**34,500**	**11,000**	**107,500**
Totals for section (using MHIs)			**29,000**	**9,000**	**92,000**
Profile CB-26					
Soil 1	52.08		17,000	5,000	54,000
		0.45	30,000	9,000	92,500
Soil 2	27.36		11,500	3,500	36,500
		0.30	12,000	4,000	39,500
Soil 3	74.45		24,500	7,500	76,500
		0.46	30,000	9,500	94,000
Soil 4	82.03		27,000	8,000	85,000
		0.43	25,500	8,000	81,500
Totals for section (using SDIs)			**80,000**	**24,000**	**252,000**
Totals for section (using MHIs)			**97,500**	**30,500**	**307,500**

UNIT CORRELATIONS

As mentioned above, as part of this scope of work, together with Leighton personnel, we attempted to correlate some of the geologic units underlying the BHHS campus with the geologic units described in the trench excavated in the 10000 site (Geocon & Feffer, 2012). The correlations made are based on elevation, texture (grain size), soil development, and other qualitative characteristics of the units that permitted a match between them. Table 6 summarizes the results of this analysis, and provides age estimates for individual units based on the soil-age estimates made both by John Helms for Geocon & Feffer, and Tania Gonzalez for ECI. The table also includes the dating results using Infra-Red Stimulated Luminescence (IRSL) provided by Dr. Ed Rhodes for the samples he collected in Leighton's trench FT-5. In general, the younger age estimates obtained from the soil-stratigraphic studies agree with the IRSL results. The deeper sediment samples (from Leighton's Unit 6) returned IRSL-derived ages that appear to be too young. Although the IRSL method is thought to be useful to date sediments at least 200,000 years old (Rhodes, 2011), it is possible that these sediments have a limited capacity to take on or trap electrons, and thus saturate at relatively low doses, meaning that the age results obtained under-represent the true age of the materials.

Table 6: Unit Correlations with Age Estimates

Geologic Units		Soils for Age Estimation				Best Age Estimate based on ECI & Helms (ka)	IRSL Age Results (ka) (Rhodes, 2012b)
Leighton FT-5	**Geocon and Feffer**	**ECI (April 2012 and this report)**	**Time Exposed to Soil Development (range based on SDI and MHI values, in ka)**	**Helms (Geocon & Feffer, 2012)**	**Time Exposed to Soil Development (in ka)**		
Unit 1	Unit 1	FT-2 Qal1-3	40	SP3, SS + BS1	30-60	30-60	52.3-66.3 (bottom Unit 1 in FT-5)
	Unit 2			SP3, BS2-4	68-135	68-135	
Unit 2	Unit 4 Upper	FT-5 Soil1	24-60	SP1, SS	30-70	54-130	
Unit 3	Unit 4 Lower	FT-5 Soil2	26-80	SP2, SS+BS1	30-70	80-200	
Unit 3a	Unit 5	FT-5 Soil3	16-69	SP1, BS1-2; SP2 BS2-3	23-45	96-245	110-144
Unit 4	Unit 6	Not described		SP1, BS3; SP2, BS4	15-30	111-275	
Unit 5	Unit 7	No soils preserved		SP3, BS5	15-30	126-305	100-128
Unit 6 (Cheviot Hills Deposits?)	Not exposed	CB-26, Soil1	17-30			143-335	121-159 (2 samples combined)

Abbreviations:
SDI = Soil Development Index; **MHI** = Mean Horizon Index (see text of report)
SP = Soil Profile; **SS** = Surface Soil; **BS** = Buried Soil (Applies to Helm's soils, see Geocon & Feffer, 2012).
ka = 1000 years

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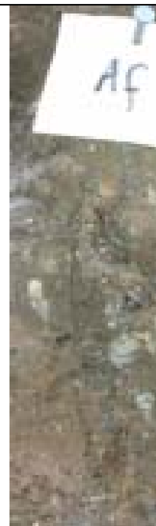
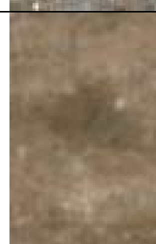
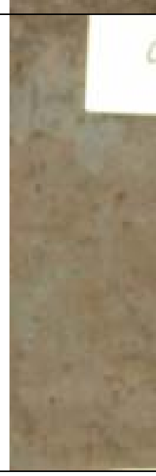
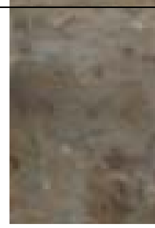
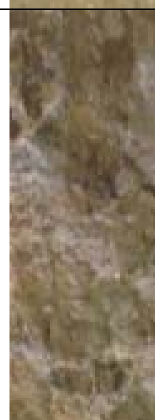
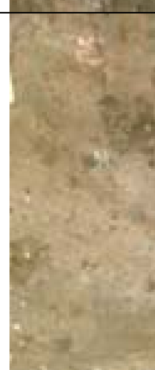
APPENDIX A:
Beverly Hills High School Trenching Project
SOIL DESCRIPTIONS

Profile No. FT-5-1 – Leighton's Fault Trench 5, East Wall at approximately Station 0+81.
Section overlain by 38 cm of concrete and road base aggregate that were not included in the descriptions below.

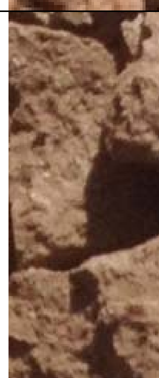
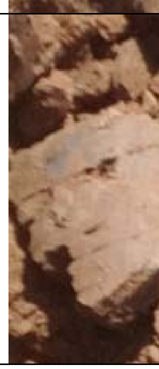
Depth (ft)	Depth (cm)	Horizon Designation	Photograph	Description
0 – 0.69	0 – 21	Af		Gravelly CLAY, mixed; dark brown; massive; abrupt wavy boundary. No samples collected.
0.69 – 0.92	21 - 28	C1 / Af		Fine SANDY LOAM; dark yellowish brown (10YR 3/4) with brown (10YR 4/3) when slightly moist, dark brown (10YR 3/3) when moist; massive; dense; loose to soft when dry, loose to very friable when moist, slightly sticky and non-plastic to slightly plastic when wet; few thin stains; abrupt wavy boundary.
0.92 – 1.48	28 - 45	C2		Very fine SANDY CLAY LOAM with lenses of medium to coarse SAND at top that pinch out laterally; dark yellowish brown (10YR 4/3.5) when slightly moist, dark yellowish brown (10YR 3/4) when moist; massive; loose to soft when dry, loose to very friable when moist, slightly sticky and slightly plastic to plastic when wet; no clay films or stains observed; abrupt wavy boundary.

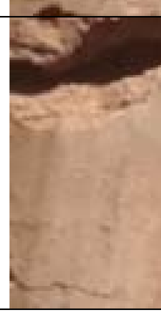
Depth (ft)	Depth (cm)	Horizon Designation	Photograph	Description
1.48 – 1.8	45 – 55	C3		SILTY CLAY LOAM; brown (10YR 4/3) with common dark to very dark grayish brown and yellowish red (5YR 4/6) mottles when dry, dark brown (10YR 3/3) when wet and mixed; massive, thinly laminated; soft when dry, friable when moist, slightly sticky and slightly plastic to plastic when wet; common thin very dark grayish (10YR 3/2) clay stains; abrupt wavy boundary.
1.8 – 2.03	55 – 62	2Ab		Fine SANDY CLAY, possibly overprinted with clay from above; brown (10YR 4/3) when dry, dark brown (10YR 3/3) when moist; massive breaking to weak fine subangular blocky structure; slightly hard when dry, firm when moist, sticky and plastic when wet; common to many thin dark yellowish brown (10YR 4/4 to 4/6) clay films on ped faces; many fine black MnO_2 nodules; abrupt to clear and wavy boundary.
2.03 – 2.62	62 - 80	2Btb1		Fine to coarse SAND CLAY; very dark grayish brown (10YR 3/2) when dry, dark brown (10YR 3/3) when moist; moderate to strong medium subangular blocky structure; very hard when dry, very firm when moist, sticky and plastic when wet; common moderately thick and many thin clay films on ped faces, continuous moderately thick clay films bridging grains; clear wavy to irregular boundary.
2.62 – 4.40	80 - 134	2Btb2		SANDY CLAY to CLAY; gleyed, dark olive brown (2.5Y 3/2) with strong brown (7.5YR 4/6) mottles when dry, dark olive brown (2.5Y 3/2) with dark brown (7.5YR ¾) mottles when moist; strong fine to medium prismatic breaking to strong fine angular blocky soil structure; hard when dry, firm when moist, sticky and plastic to very plastic when wet; common thick and many moderately thick clay films on ped faces, continuous moderately thick clay films bridging grains; black MnO_2 staining; clear wavy to irregular boundary, with scattered gravel at base.

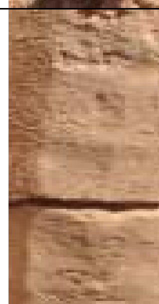
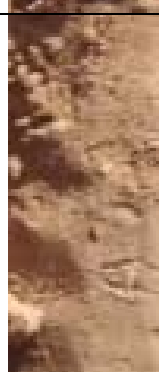
Depth (ft)	Depth (cm)	Horizon Designation	Photograph	Description
4.40 – 4.82	134 – 147	3BCb1		SANDY CLAY, overprinted with clay from above; brown (7.5YR 4/3) when dry, dark brown (7.5YR 3/3) when moist; massive breaking to moderate fine subangular blocky structure; very hard when dry, firm to very firm when moist, sticky and plastic when wet; few moderately thick and common thin dark brown (7.5YR 3/3) clay films on ped faces, many thin clay films bridging grains; MnO_2 staining; abrupt wavy boundary.
4.82 – 5.68	147 – 173	4Btb3		SANDY CLAY; very dark grayish brown (10YR 3/2) with brown (7.5YR 4/4) mottles when dry, very dark grayish brown (2.5Y 3/2) with brown (7.5YR 4/4) mottles when moist; moderate fine prismatic soil structure; very hard to extremely hard when dry, slightly firm when moist, sticky and plastic when wet; continuous thin and many moderately thick clay films on ped faces, many moderately thick clay films bridging grains; MnO_2 staining; clear wavy boundary.
5.68 – 6.14	173 – 187	5BCb2		SANDY CLAY with fine gravel, overprinted with clay from above; brown (7.5YR 4/4) with dark grayish brown (2.5Y 4/2) gleyed zones when moist, dark brown (7.5YR 3/3) when wet; massive breaking to moderate fine subangular blocky soil structure; hard when dry, firm when moist, sticky and plastic when wet; common thin clay films on ped faces, many thin clay films bridging grains; few thin $CaCO_3$ nodules, MnO_2 staining; abrupt wavy boundary.
6.14 – 6.63	187 – 202	6Btb4		SANDY CLAY to CLAY; dark brown (7.5YR 3/3 & 3/2) when slightly moist, dark brown (10YR 3/3) and dark to very dark grayish brown (2.5Y 3.5/2) when moist, dark yellowish brown (10YR 3.5/4) when mixed and wet; moderate fine prismatic breaking to moderate fine subangular blocky soil structure; very hard when dry, firm when moist, sticky and plastic when wet; common moderately thick and many thin clay films on ped faces, many moderately thick clay films bridging grains; many MnO_2 stains; clear wavy boundary.

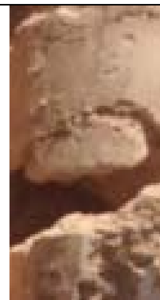
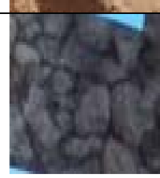
Depth (ft)	Depth (cm)	Horizon Designation	Photograph	Description
6.63 – 7.97	202– 243	6BCb3		SANDY CLAY LOAM; dark yellowish brown (10YR 4/4) when dry, dark brown (10YR 3/3) and dark grayish brown (2.5Y 4/2) when moist; massive breaking to weak fine subangular blocky structure; soft when dry, friable when moist, sticky and plastic when wet; common moderately thick clay films on ped faces, common to many moderately thick clay films in pores; few weathered gravel; clear to gradual wavy boundary.
7.97 – 8.40	243 – 256	6BCb4		SANDY CLAY to CLAY; strong brown (7.5YR 4/6) and dark gray (5Y 4/1) when moist, dark yellowish brown (10YR 4/4) and dark to very dark gray (5Y 4.5/1) when wet; massive breaking to weak fine to medium subangular blocky soil structure; soft when dry, friable when moist, sticky and plastic to very plastic when wet; few thin clay films on ped faces, many thin clay coatings on clasts; gravel up to ½-inch diameter; abrupt wavy boundary.
8.40 – 11.15+	256 – 340+	7BCb5		Fining upward sequences of sand and fine gravel to 1-inch diameter with SANDY CLAY LOAM zones; dark brown (10YR 3/3 & 7.5YR 3/3) when slightly moist, dark brown (10YR 3/3) when moist; single-grained to weak medium subangular blocky soil structure; loose to soft when dry, loose to very friable when moist, slightly sticky to sticky and slightly plastic when wet; few thin clay films on ped faces, few thin clay coatings on clasts.

Profile No. CB-23 – Leighton's Boring CB-23.
Emplaced at approximately Station 0+65 on Trench FT-5.
This core was disturbed, possibly as a result of missing teeth on the drilling bit. Although descriptions are provided herein, several sections were disturbed and are thus deemed not fully representative of the sediments underlying this location.

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
0 – 2.17	0 – 0.66	Ac	NA	According to Leighton's boring log, 8 inches of reinforced concrete over 5 inches of aggregate base, overlying 13 inches of reinforced concrete slab.
2.17 – 5.0	0.66 – 1.52	Af? / AB		SILTY CLAY; brown (10YR4.5/3) when dry, dark brown (7.5YR 3.5/3) when moist; structure not resolvable as section was hand-augered; very hard to extremely hard when dry, friable when moist, very sticky and plastic to very plastic when wet; scattered chips of slate; few $CaCO_3$ coatings.
5.0 – 5.83	1.52 – 1.78	Bt1		CLAY with gravel; brown (10YR 5/3 and 7.5YR 4/3) when dry, dark brown (10YR 3/3) when moist; massive breaking to strong coarse to very coarse angular blocky structure; extremely hard when dry, extremely firm when moist, sticky and plastic when wet; many thin to moderately thick clay films on ped faces, many moderately thick clay films on clasts, and many thin clay films bridging grains; some $CaCO_3$ coatings; very dense, compacted.
5.83 – 7.17	1.78 – 2.18	Bt2		CLAY; yellowish brown (10YR 5/4) when dry, dark yellowish brown (10YR 4/4) when moist; weak fine to medium angular blocky structure; hard to very hard when dry, very firm when moist, sticky and plastic when wet; few thin clay films on ped faces and many thin to moderately thick clay films on clasts; many clasts consisting of gneiss, granite, basalt, and slate.

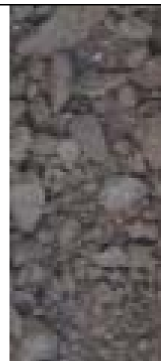
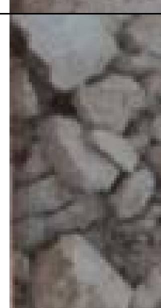
Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
7.17 – 8.67	2.18 – 2.64	Bt3		SANDY CLAY to CLAY; mottled yellowish brown (10YR 5/4), brown (7.5YR 4/4), and grayish brown (2.5Y 5/2) when dry, dark yellowish brown (10YR 3.5/4) when moist; massive; very hard when dry, very firm when moist, sticky and plastic when wet; common thin clay films on ped faces and common to many thin clay films bridging grains; 10-15% fine subrounded gravel consisting of basalt, slate, shale, and granite; many colors in core, especially at the bottom of the section.
8.67 – 10	2.64 – 3.05	NR		No Recovery
10 – 11.17	3.05 – 3.40	2C1? (disturbed)		GRAVELLY SAND; many colors; loose when dry; non-sticky and non-plastic when wet.
11.17 – 11.5	3.40 – 3.51	(disturbed)		Mixed material with concentric rings around the core; many colors and textures.
11.5 – 12.17	3.51 – 3.71	3C2		SILTY CLAY to CLAY; dark yellowish brown (10YR 4/4) when dry, dark yellowish brown (10YR 3/4) when moist; massive; extremely hard when dry, very firm when moist, sticky and plastic when wet; laminated; abundant gravel; abrupt boundary.
12.17 – 12.92	3.71- 3.94	4C3		GRAVELLY SANDY CLAY; brown (7.5YR 4/3) when dry, brown (7.5YR 5/4) when moist; massive; very hard when dry, slightly firm when moist, slightly sticky to sticky and slightly plastic when wet; 20-30% gravel; horizon feels compressed.
12.92 – 13.92	3.94 – 4.24	5C4		SANDY CLAY LOAM; strong brown (7.5YR 4/6) with strong brown (7.5YR 5/6) and grayish brown (2.5Y 5/2.5) mottles when dry, brown (7.5YR 4/4) with strong brown (7.5YR 4/6) and dark grayish brown (2.5Y 4/2) mottles when moist; massive; extremely hard when dry, very firm when moist, slightly sticky to sticky and plastic when wet; gleyed; 3-5% gravel consisting of schist and sandstone.
13.92 – 15.0	4.24 – 4.57	NR		No Recovery

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
15.0 – 17.96	4.57 – 5.47	5C5		SILTY CLAY LOAM; strong brown (7.5YR 5/6) and light brownish gray (2.5Y 6/2) when dry, brown (7.5YR 4/4) and grayish brown (2.5Y 5/2) when moist; massive; very hard to extremely hard when dry, firm to very firm when moist, slightly sticky and slightly plastic to plastic when wet; $CaCO_3$ nodules; few pinhole-sized pores; fine chips of Monterey shale; clear wavy boundary.
17.96 – 20.0	5.47 – 6.10	5C6		SANDY CLAY grading down to SILTY CLAY; brown (10YR 4.5/3) when dry, dark yellowish brown (10YR 3/4) when moist; massive; very hard to extremely hard when dry, very firm to extremely firm when moist, slightly sticky and plastic when wet; few to common thin clay films on clasts; fining downward sequence; 10-15% fine gravel with clasts up to 1.5-inch diameter consisting primarily of slate, shale, and granite.
20.0 – 20.75	6.10 – 6.32	6C7		GRAVELLY SANDY LOAM; brown (7.5YR 5/4) with grayish brown (2.5Y 5/2) mottles when dry, strong brown (7.5YR 4/6) with dark grayish brown (2.5Y4/2) mottles when moist; soft when dry, very friable when moist; sticky and non-plastic to slightly plastic when wet; fining downward sequence; large gravels up to 2-inch diameter at 20.67 feet; clear boundary.
20.75 – 23.67	6.32 – 7.21	7C8		LOAM; brown (7.5YR 5/4) with thin gleyed light olive brown (2.5Y 5/4) layers when dry, brown (7.5YR 4/4) with grayish brown (2.5Y 5/2) layers when moist; massive breaking to moderate medium to coarse subangular blocky structure; slightly hard when dry, friable when moist, non-sticky and slightly plastic when wet; dense; two fining downward sequences, first to 22.12 feet, second to bottom of section, with 2 inches of CLAYEY SAND at top of deeper section; clear boundary.
23.67 – 25.0	7.21 – 7.62	7C9		LOAM; brown (7.5YR 5/4) with light brownish gray (2.5Y 6/2) mottles when dry, strong brown (7.5YR 4/5) with light olive brown (2.5Y 5/3) mottles when moist; massive; hard when dry, slightly firm to firm when moist, slightly sticky and slightly plastic when wet; few to common clay films on clasts; mix of clasts in a fine-grained matrix; gravel up to 1-inch in diameter.

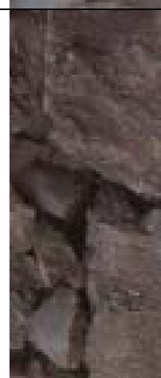
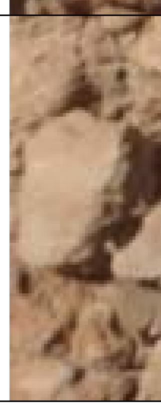
Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
25.0 – 25.58	7.62 – 7.80	7C10		LOAM; reddish yellow (7.5YR 6/6) and light brownish gray (2.5Y 6/2) when dry, brown (7.5YR 4.5/4) and grayish brown (2.5Y 5/2) when moist; massive breaking to strong coarse angular blocky structure; very hard when dry, very firm when moist; slightly sticky to sticky and plastic when wet; $CaCO_3$ nodules; few clasts; many fine pores filled with MnO_2; abrupt boundary.
25.58 – 27.25	7.80 – 8.31	8C11		Fine SAND to LOAMY fine SAND; light yellowish brown (10YR 6/4) when dry, dark yellowish brown (10YR 4/4) when moist; massive breaking to moderate medium subangular blocky structure; hard and fragic when dry, very friable when moist, non-sticky and non-plastic when wet; few scattered gravel; clear boundary.
27.25 – 30.0	8.31 – 9.14	8C12		SANDY LOAM; light yellowish brown (10YR 6/4) when dry, dark yellowish brown (10YR 4/4) when moist; massive; hard when dry, firm when moist, non-sticky to slightly sticky and non-plastic to slightly plastic when wet; gravel at top (27.25 – 27.75 feet), decreases downward; discontinuous very thin red layer at 28.75 feet.
30.0 – 30.33	9.14 – 9.25	9Ab1		SILTY CLAY; grayish brown (2.5Y 5/2) when dry, dark grayish brown (2.5Y 4/2) when moist; strong fine angular blocky structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; common thin clay films on ped faces, few to common thin clay films on clasts, common to many thin clay films lining pores; very light colored horizon with localized black MnO_2? staining; appears to be a burnt horizon; clear boundary.
30.33 – 30.83	9.25 – 9.40	9Ab2/Btb1		CLAY; dark grayish brown (10YR 4/2) with common brown (7.5YR 4/3) mottles when dry, dark grayish grown (10YR 4/2) with dark brown (7.5YR 3/3) mottles when moist; strong fine to coarse angular blocky structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; common thin and locally continuous clay films on ped faces, many thin clay films bridging grains; $CaCO_3$ filaments; MnO_2 staining, less common than above; very light and porous; appears bioturbated; gradual boundary.

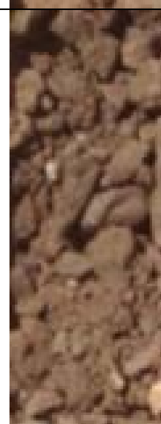
Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
30.83 – 32.67	9.40 – 9.96	9Btb2		CLAY; dark brown (10YR 3/3) with dark grayish brown (2.5Y 4/2) and dark brown (7.5YR 3/3) mottles when dry, brown (10YR 4/3) with dark grayish brown (2.5Y 4/2) and dark brown (7.5YR 3/3) mottles when moist; moderate coarse angular blocky structure; hard to very hard when dry, firm when moist, sticky and plastic when wet; common thin to moderately thick clay films on ped faces, many moderately thick clay films in pores, many moderately thick clay films bridging grains; $CaCO_3$ nodules; bioturbated, with worm castings; large clast of Monterey siltstone at 32.67 to 32.83 feet.
32.83 – 40.0	10.0 – 12.19	9BC		CLAY grades downward to SANDY CLAY; mottled dark grayish brown (10YR 4.5/2), strong brown (7.5YR 5/6), and brown (7.5YR 4/4), grading down to dark yellowish brown (10YR 4/4) with stripes of dark grayish brown (2.5Y 4/2) when dry, mottled dark brown (10YR 3/3 and 7.5YR 3/3) grading down to dark brown (10YR 3/4) with dark brown (2.5Y 4/3) stripes when moist; strong coarse to very coarse angular blocky structure; very hard to extremely hard when dry, very firm when moist, sticky and plastic when wet; common moderately thick clay films on ped faces, common thin clay films lining pores, many moderately thick clay films bridging grains; scattered clasts.

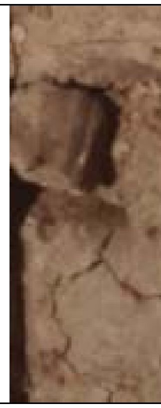
Profile No. CB-24 – Leighton's Boring CB-24
Emplaced near the north end of Leighton's trench FT-5, at approximately Station 1+10.

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
0 – 2.5	0 – 0.76	Ac / Af	NA	According to Leighton's boring log, 8 inches of concrete over 8 inches of aggregate base, overlying 12 inches of reinforced concrete. Not sampled or described.
2.5 – 7.75	0.76 – 2.36	C1		SILTY CLAY; yellowish brown (10YR 5/4) with grayish brown (2.5Y 5/2) layers when dry, brown (10YR 4/3) when moist; massive breaking to moderate medium to very coarse angular blocky structure (based on section between 5 and 7.75 feet as section above 5 feet was hand-augered; very hard to extremely hard when dry, very friable when moist, sticky and plastic when wet; few MnO_2 stains; layered/ laminated; very few scattered fine gravel; few pinhole-sized pores; clear boundary.
7.75 – 10.42	2.36 – 3.18	2Btj1		CLAY; brown (10YR 4/3) with dark gray (2.5Y 4/1) and very dark grayish brown (2.5Y 3/2) laminations when dry, brown (10YR 4/3) with very dark grayish brown (2.5Y 3.5/2) laminations when moist; massive breaking to strong coarse to very coarse angular blocky structure; very hard to extremely hard when dry, very firm when moist, sticky and plastic when wet; common thin clay films on clasts; laminated; scattered gravel up to 1.5-inch in diameter at base. No recovery between 8.9 and 10.0 but section between 10.0 and 10.42 had the same characteristics as recovered section.
10.42 – 11.92	3.18 – 3.63	3C2		SILTY CLAY; brown (7.5YR 5/4) with light brownish gray (2.5Y 6/2) layers when dry, brown (7.5YR 4/4) with dark grayish brown (2.5Y 4/2) layers when moist; moderate medium to coarse angular blocky structure; few fine pores; few scattered fine gravels; layered or "tiger striped;" clear boundary.
11.92 – 16.75	3.63 – 5.11	4Btj2		CLAY; brown (7.5YR 5/4) with grayish brown (2.5Y 5/2) mottles when dry, dark brown (7.5YR 3.5/3) with dark grayish brown (2.5Y 4/2) mottles when moist; massive breaking to moderate medium to coarse angular blocky structure; very hard when dry, slightly firm when moist, sticky and plastic when wet; few thin clay films on ped faces; few $CaCO_3$ nodules and filaments; fine MnO_2 stains; less obvious "tiger stripes" than above; few scattered gravel. No recovery between 13.83 and 15.0, but

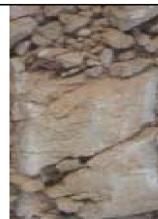
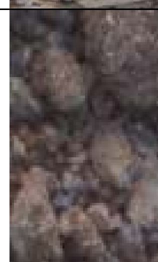
Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
				sediments below the no-recovery section were the same as above.
16.75 – 18.67	5.11 – 5.69	5C3		GRAVELLY SANDY CLAY LOAM; yellowish brown (10YR 5/4) with olive gray (5Y 5/2) laminations when dry, dark yellowish brown (10YR 3/4) with olive gray (5Y 4.5/2) laminations when moist; massive breaking to strong medium to coarse angular blocky structure; hard to very hard when dry, slightly firm when moist, sticky and plastic when wet; laminated; about 10% gravel consisting of slate, granite, and Monterey shale chips; more gritty than above; abrupt boundary defined by a stone line.
18.67 – 20.25	5.69 – 6.17	6C4		SANDY CLAY LOAM; light olive brown (2.5Y 5/3) when dry, brown (10YR 4/3) when moist; massive; very hard when dry, slightly firm when moist, sticky and slightly plastic when wet; crudely bedded; about 30% fine gravel consisting predominately of Monterey shale; gradual boundary.
20.25 – 22.92	6.17 – 6.99	6C5		Fine SANDY CLAY LOAM; dark yellowish brown (10YR 4/4) with dark grayish brown (2.5Y 4/2) and brown (7.5YR 4/4) mottles when dry, dark yellowish brown (10YR 3.5/4) with dark gray (2.5Y 4/1) and dark brown (7.5YR 3.5/4) mottles when moist; massive breaking to moderate coarse to very coarse angular blocky structure; very hard when dry, friable to slightly firm when moist, slightly sticky and slightly plastic to plastic when wet; some brown (7.5YR 4/4) clay stains that increase downward; few mottles; scattered MnO_2 stains; scattered clasts up to 1-inch diameter.
22.92 – 24.92	6.99 – 7.60	6C6		Fine SANDY CLAY LOAM to SANDY CLAY; brown (7.5YR 4/4) with light brownish gray (2.5Y 6/2) to light yellowish brown (2.5Y 6/3) varves ("tiger stripes") when dry, dark brown (7.5YR 3.5/4) with dark grayish brown (2.5Y 4/2) varves when moist; massive breaking to moderate coarse to very coarse angular blocky structure; very hard when dry, slightly firm when moist, slightly sticky and slightly plastic to plastic when wet; brown (7.5YR 4/3) clay stains; $CaCO_3$ filaments coincide with gleyed varves (or "tiger stripes").
24.92 – 25.0	7.60 – 7.62	NR		No Recovery

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
25.0 – 27.42	7.62 – 8.36	7C7		Fine SANDY LOAM to LOAM; brownish yellow (10YR 6/6) with pale yellow (2.5Y 7/3) varves when dry, dark yellowish brown (10YR 4/6) with light olive brown (2.5Y 5/3) varves when moist; massive breaking to weak to moderate fine angular blocky structure; slightly hard to hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few MnO_2 stains; $CaCO_3$ filaments that parallel laminations; clear boundary.
27.42 – 30.04	8.36 – 9.16	8C8		Fine SANDY CLAY; light yellowish brown (2.5Y 6/3) with reddish yellow (7.5YR 6/6) varves when dry, olive brown (2.5Y 4/3) with reddish yellow (7.5YR 6/6) varves when moist; massive; very hard to extremely hard when dry, very firm to extremely firm when moist, sticky and plastic when wet; more clasts than above; common dark brown (7.5YR 3/3) MnO_2 stains; several "red" laminations, the most prominent one at 28.38 feet; gravelly section at 29-29.42 feet; few $CaCO_3$ nodules.
30.04 – 31.25	9.16 – 9.53	9C9		Fine to medium SANDY LOAM; light brownish gray (10YR 6/2) and strong brown (7.5YR 5/6) when dry, brown (10YR 4.5/3), strong brown (7.5YR 5/6), and olive brown (2.5Y 4/3) when moist; weak medium subangular blocky structure; soft to slightly hard when dry, friable when moist, slightly sticky to sticky and non-plastic to slightly plastic when wet; MnO_2 stains; about 20% gravel up to 1-inch diameter; abrupt boundary.
31.25 – 32.96	9.53 – 10.05	9C10		Fine SANDY CLAY LOAM grades down to fine to coarse SANDY LOAM at bottom; light brownish gray (2.5Y 6/2) with brown (7.5YR 5/4) layers when dry, olive (5Y 5/3) with brown (7.5YR 4/4) layers when moist; massive breaking to moderate medium to coarse angular blocky structure; hard when dry, slightly firm when moist, slightly sticky to sticky and plastic when wet; fining upward sequence; varved; 3-5% scattered gravel consisting of angular to subrounded chips of slate and Monterey shale up to 1-inch diameter; abrupt boundary.

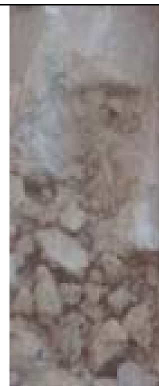
Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
32.96 – 33.83	10.05 – 10.31	10C11		GRAVELLY LOAMY fine to coarse SAND; brown (10YR 5/3) with yellowish red (5YR 4/6) and dark yellowish red (5YR 3/3) layers when dry, dark yellowish brown (10YR 3/4) with dark yellowish brown (10R 4/6 and 3/4) layers when moist; weak medium subangular blocky structure; soft when dry, friable when moist, non-sticky and non-plastic when wet; abundant FeO and black MnO_2 stains on clays, and along some layers; angular to subangular gravel-sized chips of Monterey shale; clear boundary.
33.83 – 36.5	10.31 – 11.13	10C12		LOAMY fine to coarse SAND; dark grayish brown (10YR 4/2) with yellowish red (5YR 4/6) and light yellowish brown (10YR 6/4) mottles when dry, dark gray (10YR 4/1) with brown (10YR 4/3) and yellowish red (5YR 4/6) mottles when moist; weak medium subangular blocky structure; soft to very hard when dry, friable when moist, slightly sticky and non-plastic when wet; disturbed; clay rich zone at 34.67'; locally gravelly with clasts up to 3-inch diameter, clast-supported sections consisting predominantly of slate and shale, angular in shape and randomly oriented; abrupt boundary.
36.5 – 37.79	11.13 – 11.52	11C12		Very fine SANDY CLAY LOAM with interbedded very fine to medium SAND; light yellowish brown (10YR 6/4) with strong brown (7.5YR 5/6) and light gray (2.5Y 7/2) mottles and lamellae when dry, dark yellowish brown (10YR 4/4) with dark grayish brown (2.5Y 4/2) and strong brown (7.5YR 4/6) mottles and lamellae when moist; massive breaking to weak fine subangular blocky structure; soft to slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; laminated/ thinly bedded depositional unit that includes beds of fine to very fine sand and silt; abrupt boundary.
37.79 – 38.5	11.52 – 11.73	11C13		LOAMY fine SAND; pale brown (10YR 6/3) with strong brown (7.5YR 5/6) mottles/ layers when dry, brown (10YR 4/3) with dark brown (7.5YR 3/4) mottles/ layers when moist; massive; soft when dry, friable when moist, non-sticky and non-plastic when wet; MnO_2 staining, locally with large MnO_2 stains; 3-5% fine, mostly rounded gravel; laminated to thinly bedded.

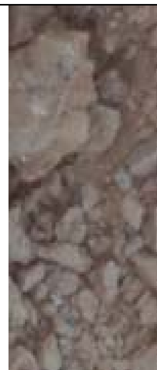
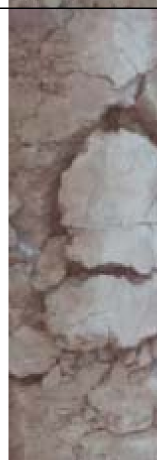
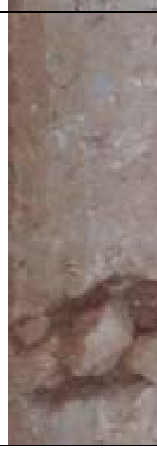
Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
38.5 – 40.17	11.73 – 12.24	12C14		CLAY; very dark grayish brown (10YR 3.5/2) with strong brown (7.5YR 5/8) mottles when dry, very dark grayish brown (10YR 3/2) with dark brown (7.5YR 3/4) mottles when moist; massive breaking to strong coarse angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; common MnO_2 stains; some polished surfaces; scattered fine gravel; abrupt boundary. Units between 40′ and 50′ are varved, predominately gleyed, with some clay films or polished surfaces.

Profile No. CB-26 – Leighton's Boring CB-26
Located at the south end of Trench FT-5, at approximately Station 0+00.

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
0 – 2.3	0 – 0.71	ND		Not described and not sampled.
2.3 – 3.96	0.71 – 1.21	C1		SILTY fine SAND. Not sampled or described.
3.96 – 5.92	1.21 - 1.80	2C2		GRAVELLY SAND. Not sampled or described.
5.92 – 7.92	1.80- 2.41	3C3		CLAYEY SAND with GRAVEL to GRAVELLY SANDY CLAY. Not sampled or described.
7.92 – 8.62	2.41 – 2.63	4Ab		SANDY LOAM, brown (7.5YR 4/3.5) when damp, dark brown (7.5YR 3/2) when moist; friable to very friable when moist; sticky and plastic when wet; few to common thin clay films on clasts and few to common thin clay films bridging grains; few scattered rounded fine gravel.
8.62 - 10	2.63 – 3.05	NR		No Recovery
10 – 11.17	3.05 – 3.40	4Btb1		SANDY CLAY; brown (7.5YR 5/3) with pinkish gray (7.5YR 6/2) mottles when dry, brown (7.5YR 4/4) when moist; strong fine subangular blocky structure; very hard when dry, firm when moist, sticky to very sticky and plastic when wet; common to many moderately thick clay films on ped faces, continuous moderately thick to thick clay films on clasts, many moderately thick clay films bridging grains, many moderately thick clay films lining pores; scattered fine gravel.

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
11.17 – 12.12	3.40- 3.70	4Btb2		CLAY to SILTY CLAY; brown (7.5YR 4/3) and gray (5Y 5/1) when dry, brown (7.5YR 4/4) and dark gray (5Y 4.5/1) when moist, brown (10YR 4/3) when mixed and wet; moderate to strong fine angular blocky structure; hard when dry, firm when moist, very sticky and plastic when wet; many moderately thick clay films lining pores; many fine pinhole-sized pores; thin gray laminations; gleyed; large broken granite cobble defining abrupt boundary.
12.12 – 13.08	3.70 – 3.99	5Ab/Btjb		LOAMY SAND to SAND; brown (7.5YR 4/3) when dry, dark brown (7.5YR 3.5/2) when moist; soft when dry, very friable when moist, non-sticky and non-plastic when wet; few to common thin clay films on ped faces and few to common thin clay films bridging grains; scattered fine subangular to platy gravel up to 1.5-inch in diameter; clear to abrupt boundary.
13.08 – 14.5	3.99 – 4.42	5Cb1		Fine SANDY CLAY; brown (7.5YR 5/4 to 4/4) and olive gray (5Y 5/2) when dry, brown (7.5YR 4/3) and dark olive gray (5Y 3/2) when moist; massive; very hard when dry, firm when moist, sticky and plastic when wet; no pores visible; grey, black, and red laminations; scattered angular chips of Monterey Fm. ½- to 1-inch in diameter; clear wavy boundary.
14.5 – 15.58	4.42 – 4.75	5Cb2		Fine SANDY CLAY to SILTY CLAY; yellowish brown (10YR 5/4) with grayish brown (2.5Y 5/2) stains in root pores when dry, dark yellowish brown (10YR 4/4) with grayish brown (2.5Y 5/2) stains in root pores when moist; massive; very hard to extremely hard when dry, very firm to extremely firm when moist, sticky and plastic when wet; MnO_2 staining; few scattered fine-grained $CaCO_3$ nodules; clear wavy boundary.
15.58 – 17.5	4.75 – 5.33	6Btb3		CLAY grading downward to SANDY CLAY; dark brown (7.5YR3/3) with dark brown (7.5YR3/2) clay films when dry, dark brown (7.5YR3/2.5) when moist; moderate medium to coarse angular blocky structure; slightly hard when dry, slightly firm when moist, very sticky and very plastic when wet; common to many moderately thick clay films on ped faces, common moderately thick clay films bridging grains; no visible pores; few $CaCO_3$ nodules; scattered clasts of Santa Monica slate; gradual boundary.

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
17.5 – 18.17	5.33 – 5.54	6Btb4		CLAY; dark brown (7.5YR 3/2) and brown (7.5YR 4/4) with very dark gray (2.5Y 3/1) mottles when dry, dark brown (7.5YR 3/3) with dark grayish brown (2.5Y 4/2) mottles when moist; strong medium to coarse angular blocky structure; very hard when dry, slightly firm when moist, very sticky and very plastic when wet; common moderately thick clay films on ped faces and many moderately thick clay films bridging grains; few fine $CaCO_3$ nodules; fewer and smaller clasts of Santa Monica slate than horizon above.
18.17 – 20	5.54 – 6.10	7Btb5		SILTY CLAY with fine sand and gravel; brown (7.5YR 4/4) with gray (2.5Y 5/1) mottles when dry, brown (7.5YR 4/3.5) with dark grayish brown (2.5Y 4/2) mottles when moist; moderate coarse angular blocky structure; very hard to extremely hard when dry, friable when moist, very sticky and very plastic when wet; common thin clay films on clasts, few to common thin clay films on ped faces, common thin clay films lining pores; common MnO_2 staining; many (about 10%) angular fine gravel-sized chips of Santa Monica slate.
20 – 20.5	6.10 – 6.25	8BCb1		Fine SANDY CLAY; dark yellowish brown (10YR 4/4) with brown (7.5YR 4/4) clay films and dark gray (2.5Y 4/1) mottles when dry, brown (10YR 4/3) with brown (7.5YR 4/4) clay films and dark grayish brown (2.5Y 4/2) mottles when moist; weak to moderate medium angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; few thin clay films on ped faces and common to many clay films bridging grains; with 2-3% gravel-sized chips of Santa Monica slate; clear boundary.
20.5 – 21.67	6.25 – 6.60	$8C_{lam}b1$		SILTY CLAY; yellowish brown (10YR 5/4) and dark grayish brown (2.5Y 4/2) with brown (7.5YR 4/3.5) Bt_{lams} when dry, dark yellowish brown (10YR 4/4) and dark grayish brown (2.5Y 4/2) with brown (7.5Y 4/4) Bt_{lams} when moist; massive breaking to weak coarse angular blocky structure; soft when dry, friable when moist, very sticky and very plastic when wet; common clay films on ped faces in the Bt lamellae; primary sedimentary structure consisting of laminations and secondary soil lamellae; clear boundary.

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
21.67 – 22.75	6.60 – 6.93	9Btb6		Fine SANDY CLAY; brown (7.5YR 4/3) with dark gray (2.5Y 4/1) mottles when damp, brown (7.5YR 4/3) with very dark grayish brown (2.5Y 3/2) mottles when moist; weak fine to medium angular blocky structure; friable when moist, sticky and plastic when wet; few to common thin clay films on ped faces and few to common thin clay films lining pores; about 5% angular gravel up to 1-inch in diameter that includes Santa Monica slate and Monterey Fm. shale; clear boundary.
22.75 – 27.92	6.93 – 8.51	$9C_{lam}b2$		SANDY LOAM (matrix) and LOAM (Bt lamellae), fining downward section; yellowish brown (10YR 5/4) with dark yellowish brown to brown (10-7.5YR 4/4) Bt zones when dry, dark brown (10YR 3.5/3) with dark yellowish brown (10YR 4/4) Bt zones when moist; massive breaking to moderate fine to medium angular blocky structure; soft when dry, friable when moist, slightly sticky and non-plastic to slightly plastic when wet; clay films in the Bt zones include common to many thin clay films on ped faces and common to many thin clay films bridging grains; lamellae throughout the horizon are up to about 1-inch thick (thicker than in $3C_{lam}b_1$).
27.92 – 30	8.51 – 9.14	$10C_{lam}b3$		CLAY; dark yellowish brown (10YR 4/4) with dark brown (7.5YR 3/2) lamellae when dry, dark yellowish brown (10YR 3/4) with dark brown (7.5YR 3/3) lamellae when moist; massive breaking to moderate medium to coarse angular blocky structure; dense; very hard to extremely hard when dry, firm when moist, sticky and plastic when wet; common thin clay films on ped faces and many thin to moderately thick clay films on clasts; very thin discontinuous light red (10R 6/8) layer at 29.77 feet (9.07m); about 5% gravel consisting of chips of Santa Monica shale and Monterey slate; scattered $CaCO_3$ nodules.

Depth (ft)	Depth (m)	Horizon Designation	Photograph	Description
30 – 33.38	9.14-10.17	10Cb3		SILTY CLAY; yellowish brown (10YR 5/4) with dark grayish brown (10YR 4/2) and light gray (2.5Y 7/2) mottles when dry, dark yellowish brown (10YR 4/4) with dark brown (10YR 3/3) and grayish brown (2.5Y 5/2) mottles when moist; massive breaking to weak fine to medium angular blocky structure; slightly hard when dry, friable when moist, sticky to very sticky and plastic when wet; common to many thin clay films on clasts; common MnO_2 stains; between 31.67 and 32.5 feet (9.65-9.91m) there is an increase in gravel consisting of angular chips of Santa Monica slate and Monterey shale up to 1-inch in diameter; abrupt wavy boundary.
33.38 – 34.17	10.17 – 10.41	11Cb4		LOAMY SANDY GRAVEL; yellowish brown (10YR 5/4) when dry, brown (10YR 4/3) when moist; weak fine subangular blocky structure; soft when dry, very friable when moist, slightly sticky and non-plastic when wet; up to 30% gravel consisting predominately of schist and slate.
34.17 – 35	10.41 – 10.67	12Cb5		SILTY CLAY; mottled yellowish brown (10YR 5/4), brown (10YR 4/3), and light brownish gray (2.5Y 6/2) when dry, mottled brown (10YR 3/4), grayish brown (2.5Y 5/2), and light olive brown (2.5Y 5/3) when moist; massive breaking to weak fine to medium angular blocky structure; slightly hard to hard when dry, slightly firm to firm when moist, sticky and plastic when wet; sandier zone between 34.6 and 34.75 feet (10.54-10.6 m); laminated; MnO_2 stains; extensively mottled; few scattered fine chips of Monterey shale and Santa Monica slate.
35 – 40	10.67 – 12.19	13Cb6		LOAMY SAND; dark yellowish brown (10YR 4/4) when damp, dark brown (10-7.5YR 3/3) when moist; massive breaking to weak medium angular blocky structure; soft when dry, very friable when damp, non-sticky and non-plastic when wet; few to common thin clay films on ped faces; MnO_2 stains; fining downward sequence; 4-inch thick sand layer starting at 35.5 feet (10.82 m); followed by interbedded sand and silt; few to common fine pores.

PEDOCHRONOLOGICAL REPORT FOR BEVERLY HILLS HIGH SCHOOL, BEVERLY HILLS, CALIFORNIA

Leighton Consulting, Inc., Irvine, CA, Project No. 603314-001

12 May 2012

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INTRODUCTION

An assessment of seismic and landslide risk due to ground movement can be aided greatly by the techniques of pedochronology (Borchardt, 1992, 1998, 2002), soil dating. This is because the youngest geological unit overlying fault traces and landslide features is generally a soil horizon. The age and relative activity of ground movement often can be estimated by evaluating the age and relative disturbance of overlying soil units.

Soil horizons exhibit a wide range of physical, chemical, and mineralogical properties that evolve at varying rates. Soil scientists use various terms to describe these properties. A black, highly organic "A" horizon, for example, may form within a few centuries, while a dark brown, clayey "Bt" horizon may take as much as 40,000 years to form. Certain soil properties are invariably absent in young soils. For instance, soils developed in granitic alluvium of the San Joaquin Valley do not have Munsell hues redder than 10YR until they are at least 100,000 years old (Birkeland, 1999; Harden, 1982). Still other properties, such as the movement and deposition of clay-size particles and the precipitation of calcium carbonate at extraordinary depths, indicate soil formation during a climate much wetter than at present. In the absence of a radiometric age date for the material from which a particular soil formed, an estimate of its age must take into account all the known properties of the soil and the landscape and climate in which it evolved.

METHOD

The first step in studying a soil is the compilation of the data necessary for describing it (Birkeland, 1999; Borchardt, 2010). At minimum, this requires a Munsell color chart, hand lens, acid bottle, meter for 1:1 soil:water pH and conductivity measurements. The second step may involve the collection of samples of each horizon for laboratory analysis of particle size. This is done to check the textural classifications made in the field and to evaluate the genetic relationships between horizons and between different soils in the landscape. When warranted, the clay mineralogy and chemistry of the soil also is analyzed to provide additional information on the changes undergone by the initial material from which the soil weathered. The last step is the comparison of this accumulated soil data with that for soils having developed under similar conditions. Such information is scattered in soil survey reports (e.g., Welch, 1981), soil science journals, and consulting reports. In a particular locality, there is seldom enough comparative data available for this purpose. That is why, at the very least, the study of one soil profile always makes the evaluation of the next that much easier.

RESULTS OF THIS EVALUATION

Soil Profile No. 1 (FT-1 Station 0 + 43)

Soil Profile No. 1 was studied to assess the age of the alluvial surface in Trench FT-1 at Station 0 + 43 at Beverly Hills High School (Table 1). This relict paleosol (fossil soil) is the best developed soil on the site, mostly because it has escaped the pervasive erosion and deposition affecting the other soils. The Ap horizon (“p” was originally used for plow, but I now use it for “people,” meaning that it is a disturbed horizon produced by Homo sapiens, whether plowed or not) (Table 1). Here it is simply artificial fill. The underlying 20-cm thick brown silty clay loam is an A horizon that probably has had a considerable contribution from aeolian silts. The underlying 2Bt horizon is a brown clay with coarse to medium moderate angular blocky structure and common thin patchy clay films on sand grains and peds (Figure 1). Then follow two more Bt horizons to the 209-cm depth. These have many thin to medium thick clay films on sand grains, gravels and in pores. The relatively flat-lying bedding becomes even more apparent as the underlying brown to dark yellowish brown BCt and CBt horizons extend to over 440 cm (Figure 2).

Soil conductivity measurements show that the salt content of the Bt horizon is high (Figure 3), while the pH is rather uniform except for the vegetative recycling effect at the surface (Figure 4). When this soil first formed during the Pleistocene, the salt content of the Bt horizon would have been low as a result of the leaching that occurred along with translocation of the clays that now appear as films on sand grains, clasts, pores, and interstices. The precipitation in the region during the Pleistocene was two to three times what it is at present (McFadden, 1982). The currently dry climate (13”/yr) has insufficient moisture to remove the salts. The conductivity measurement helps establish the fact that this profile initially formed during the Pleistocene rather than during the Holocene.

Comparative Pedochronology

The geology map of Meigs and others (1999) shows the area underlying Beverly Hills High School (BHHS) as “late Pleistocene.” This is normally considered the time since 122 ka, when Sangamon sea level reached +6 m, inundating low-lying areas along the California coast during marine isotope stage (MIS) 5e. Subsequent regression left behind marine sands that were eventually buried by alluvium. The regression vacillated, producing MIS 5c and 5a¸ with the terrace materials being left stranded above sea level after 80 ka during the Wisconsin glaciation. We can compare Soil Profile No. 1 with some of the soils on relatively well-dated terraces along the coast—with one caveat. Pedogenesis is high dependent on the properties of the initial material. The ideal situation for the production of thick Bt horizons involves the juxtaposition of clayey overbank materials over porous gravels and coarse sands. Thus, when marine sands on the Sangamon terrace at Bodega Bay were not augmented with alluvium, Bt horizons were as little as 20-cm thick even though 7.5YR colors reached depths of 3.8 m or more (Borchardt, 1993). Colors redder than 10YR were not produced on a Sangamon terrace at Point Pinole when silt contents of the alluvium were especially high (Borchardt, 1988). Soils on terraces with ages greater than 122 ka typically have much redder colors than those seen in Soil Profile Nos. 1 and 6. For instance, a soil on a terrace near Torrey Pines, which might be as old as early Pleistocene, had red 2.5YR colors reaching depths over 5.8 m (Torrent and others, 1980a). On the other hand, a possible Sangamon terrace at San Diego had mostly 10YR loamy sand with a few clay lamellae having 7.5YR and 5YR colors reaching a depth of 4.2 m (Torrent and others, 1980b). Closer to our site, the Ventura River terraces start having 7.5YR colors after 38 ka, but do not have 5YR colors until after 80 ka (Rockwell and others, 1985, p. 317). Similarly, Soil Profile No. 1 is at least 80,000 years old.

Soil Profile No. 2 (FT-2 Station 0 + 85)

This soil profile from Trench FT-2 at Station 0 + 85, at a lower elevation than Soil Profile No. 1, is overlain by 55 cm of fill (Table 2). The underlying 35-cm thick ABt is a dark brown gravelly clay loam that includes an eroded remnant of a Bt horizon that became the parent material of a new A horizon. It has a few medium to fine distinct red mottles due to peds eroded from a previous landscape. It has fine to coarse strong subangular blocky structure and common thin patchy clay films on sand grains and pores. Beneath this are brown silty clay BCt and CBt horizons that have medium thick patchy clay films in pores and interstices to the 214-cm depth. Beneath this is a reddish moderately well developed paleosol that has a 3Btb horizon that consists of brown silty clay with a few medium distinct light red mottles, medium to coarse strong subangular blocky structure, and many medium thick clay films lining pores and coating peds (Figure 5). Thin to medium thick clay films extend through brown BCt and CBt silty clay to gravelly clayey sand horizons to the 440-cm depth excavated. A prominent channel, now filled with gravel, cut the paleosol as well as the overburden above it (Figure 6).

As might be expected for a currently active soil, the conductivity of the upper horizons was low due to leaching (Figure 3). Salts leached from the solum were deposited in the 3CBt horizon. Similarly, salts were leached out of the upper horizons of the paleosol to be deposited in the 4BCtb horizon. This may be a remnant of previous Pleistocene climatic conditions. Salts from the modern soil have not yet reached the lower part of the paleosol.

Soil Profile No. 3 (FT-2 Station 2 + 15)

This profile, from Trench FT-2 at Station 2 + 15, has a 50-cm thick very dark grayish brown clay loam A horizon beneath the fill (Table 3). The 30-cm thick dark grayish brown B horizon is sandy clay with medium strong subangular blocky structure. Beneath this is a 96-cm thick dark brown gravelly sandy clay 2B horizon with strong subangular blocky structure and a few thin clay films in pores and on sand grains. Beneath this are dark yellowish brown 2BCt1 and brown 2BCt2 sandy clay horizons that have moderate to strong subangular blocky structure and common thin clay films in pores and on peds to the 290-cm depth. Beneath this is a moderately well developed paleosol having a 69-cm thick grayish brown clay 2Btb horizon with medium strong angular blocky structure and common thin clay films in pores and on peds. Beneath this are dark brown to dark yellowish brown clay to gravelly clay 2CBtb horizons with medium moderate to strong subangular blocky structure and common thin clay films in pores and on peds and sand grains to the 455-cm depth of the excavation.

The conductivity in this soil profile increases steadily with depth (Figure 3). I speculate that this may reflect the dry climate that existed both before and after the cutting that occurred between 80 and 20 ka when fluvial conditions returned with increased precipitation during isotope stage 4 (Table 3). The other possibility is that the conductivity pattern could be a single overprint that reflects an increase in precipitation and aggradation that leaves previously accumulated salts behind.

Portions of the paleosol lying closer to what was once a channel margin had tilted peds (Figure 7). Prismatic and angular blocky peds like these form because of shrink-swell in clayey horizons like this 2Btb. Ped boundaries normally are either vertical or horizontal. On hillsides, however, soil creep causes the upper parts of the soil to creep faster than the lower parts, mostly because the annual changes in moisture content are greater in the surface than at depth. In this case, a channel fill margin of prehistoric Benedict Canyon lies immediately to the east. It no doubt provided the free face that allowed this eastern portion of the 2Btb horizon to creep downhill when the channel was active. No tectonic significance should be attributed to these features.

Soil Profile No. 4 (FT-2 Station 2 + 80)

This profile, from Trench FT-2 at Station 2 + 80, was formed on a relatively level river terrace that is part of the Benedict Canyon fluvial system east of BHHS. Soil Profile No. 4 consists of two parts: a cumulic solum formed during the late Holocene and a paleosol formed after the mid-Wisconsin highstand, which occurred during MIS 3 at about 41 ka (Anderson, 1993) (Table 4). Before and after that time, Benedict Canyon would have had much steeper gradients. During MIS 2, for instance, it would have debouched into an ocean that was as much as 120 m lower than it is at present. As sea level rose after that 22-ka transgression, Benedict Canyon began to fill with sediments eroded from the Santa Monica Range to the north. By the late Holocene, the relatively fine flood or debris-flow deposits comprising the cumulic soil began to arrive at the site.

Most soils have only one A horizon, which is generally 20-30 cm thick. This profile, however, has at least four (Ap, A1, A2, and A3), with a total thickness of 189 cm. The 25-cm thick Ap horizon is fill that probably dates from school construction. The 38-cm A1 horizon is a dark brown silty clay loam with coarse strong subangular blocky structure with a few thin clay films in pores and interstices. The underlying 64-cm thick A2 horizon is a dark brown sandy loam. Its relatively low conductivity (290 uS) probably indicates that the historical wetting front reached its base at 127 cm (102 cm beneath the fill of the Ap). Although its medium strong granular structure prevents it from being classified as a B horizon, it is apparent that it is in the initial stages of such development. The horizon beneath it, the 62-cm thick dark brown silty clay loam A3, forms two functions in this profile. First, it has some of the characteristics normally associated with a BC horizon: a few thin clay films in pores and interstices and bridging sand grains and an increase in conductivity (390 uS) (Figure 3). Second, at least its lower half probably was the A horizon for the rest of the solum beneath it.

The underlying moderately well-developed soil has a 33-cm thick brown gravelly sandy clay loam with medium moderate subangular blocky structure and common thin patchy clay films bridging sand grains. Its conductivity (230 uS) is lower than the horizon above and the horizon below, indicating that it was leached, although not enough to eliminate the increase in pH that occurred there (Figure 4). The 54-cm thick Btb is a brown clay with medium strong subangular blocky to prismatic structure and many thin to medium thick continuous clay films bridging sand grains and coating pores, peds, and angular slate clasts. The underlying horizon is a brown sandy clay BCtb with a few thin to medium thick continuous clay films bridging sand grains and coating pores, peds, and angular slate clasts. The underlying horizon is a grayish brown clayey sand 2CBtb with a few thin to medium thick continuous clay films. Beginning at the 383 depth, the unweathered "parent materials" appear as grayish brown gravelly sand and brown light clayey sand. These simply reflect the upward fining sequence common to the filling phase of fluvial systems. They should not be considered to be the initial state that formed the overlying B horizons.

Soil Profile No. 5 (FT-3 Station 0 + 57)

This profile was from Trench FT-3, at Station 0 + 57, which was just south of Trench FT-1 where Soil Profile No. 1 was described. Unlike that soil, Soil Profile No. 5 had been graded, leaving only BCt and CBt horizons behind (Table 5). The first horizon beneath the asphalt and road base was a 94-cm thick reddish brown gravelly clayey sand BCt1 with massive to fine weak subangular blocky structure and many medium thick clay films in interstitial pores and bridging sand grains (Figure 8). The second was a 34-cm thick reddish brown sand BCt2 with similar structure and clay film development. The third was a 4-cm thick brown gravel 2BCt with massive structure and similar clay film development. The fourth was a 169-cm thick brown sandy gravel 3BCt with many medium thick to thick clay films. The fifth was a 128-cm thick yellowish brown clayey sand 4CBt horizon with clay film development like the horizon above it. This relict paleosol correlates with and is the same age as the one described in Trench FT-1 as Soil Profile No. 1 (compare Table 1 and Table 5).

Soil Profile No. 6 (CB-13)

Soil Profile No. 6 was studied to assess the age of the alluvial surface immediately north of Beverly Hills High School. Samples were measured, sampled, and described through examination of continuous core boring CB-13. The core had numerous 1-cm thick varves (Figure 9), whose formation was occasionally interrupted by soil development (Table 6). Seasonal alternations in precipitation when the climate was cooler apparently produced the clayey gray, low redox zones in the winter and sandy yellowish brown high redox zones in the summer. The core had five paleosols (Table 6), with the best developed one being encountered at a depth of 25’ (elevation of 241’). It was a well-oxidized 2-m thick paleosol sandwiched between two sets of varves at the 762-970 cm interval.

Overall, soil development in this core appears to be about half that observed in core CB-3, which is 0.2 km to the south (ECI, 2012). The comparison is best seen by simply adding up the thicknesses of the Bt horizons. In CB-3 they are, from top to bottom, (in feet): 8, 7, 1, 7, 1, 1, 4, and 6, for a total of 35 feet. The upper soil, at 8 feet thick, is considered to have at least 80 ky of soil development. This would make the entire section about 350 ka, which implies that the abrasion platform above the San Pedro Formation is at least MIS 9, as implied by Lindvall and others (2001). Meigs and others (1999) classification of the area underlying the school as “late Pleistocene” is technically true only for the surface of the section.

Applying the same calculation to the CB-13 core yields about 15 feet of Bt horizon, which, at the 10 ky/ft rate would indicate a soil development age of only 150 ky. Despite its conspicuous lack of unconformities (only one gravel layer), this site must have had considerable erosion. When not being eroded, it probably was a marsh much of the time, as shown by the varves (Figure 9). Again, this shows the pronounced effect of pluvial conditions on preventing soil development. CB-3 is 16 feet higher than CB-13, and so was well drained for much of the time. The marshy conditions that enveloped CB-13 simply did not reach CB-3 very often. Soils simply do not form in lakes. In some parts of the West, pluvial conditions prevent soil development entirely, supporting the over-generalized claim that soil development is faster during interglacial periods than during glacial periods (Morrison, 1978).

DISCUSSION

This study of the late Pleistocene soils overlying the eastern limb of the anticline at Beverly Hills High School uncovered no evidence of active faulting. Faults projected into the area by Parsons Brinckerhoff (2011) were not found in Trenches FT-1 through FT-4. In the vicinity of Soil Profile No. 6 (CB-13), the “estuarine” sediments mentioned in that report are mostly varved fresh-water marsh deposits—conductivities are relatively low (Table 6). The color and thickness of the relict paleosol in Soil Profile No. 1 is similar to that of other sandy soils formed after the last major interglacial period (Borchardt, 1993). The development of Soil Profile No. 1 spans the Wisconsin glacial period when precipitation in the area probably was two to three times that at present (McFadden, 1982). Seven paleosols underlie the relict Sangamon soil, as seen in core boring CB-3 (ECI, 2012). Two of these were observed in Trench FT-2 at Stations 0 + 85 (Table 2) and 2 + 15 (Table 3).

The youngest soil at the site was developed in a terrace sequence in Trench FT-2 at Station 2 + 85 (Table 4). This western margin of Benedict Canyon presumably was cut during the early Wisconsin, when sea level was much lower than it is today. Backfilling commenced during the mid-Wisconsin, after 41 ka, forming the terrace in which the paleosol in Soil Profile No. 4 developed. The overlying modern soil appears to have been deposited upon the next occasion for terrace formation along Benedict Canyon—the Holocene. Multiple A horizons attest to a process dependent on the high base level and low stream gradients of the present day.

The description of Soil Profile No. 5 from Trench FT-3 (Table 5) was similar to that of the lower half of the 80-ka soil in Trench FT-1 (Table 1). The A and Bt horizons in Trench FT-3 had been removed by grading during construction of the school.

A comparison of core borings CB-3 (ECI, 2012) and CB-13 (Table 6) showed their widely divergent pedochronology. In essence, the strong soil development present at the top and bottom of CB-3 was absent in CB-13. Only one of the five paleosols (b3) in CB-13 had strong development. Simply adding up the total thicknesses of Bt horizons for each core gave 35' for CB-3 and only 15' for CB-13. The differences are probably due to erosion and/or to the greater prevalence of marshy conditions in CB-13, as indicated by the 1-cm thick seasonal varves that dominate that core.

CONCLUSIONS

1. Soil Profile No. 1 is over 80,000 years old.
2. All soil profiles examined were older than 11,000 years, making them ideal for seismic hazard analysis. The youngest, Soil Profile No. 4, in the channel fill at the eastern end of Trench FT-2 is estimated to be 41 ka.
3. The wave-cut platform underlying the old alluvium at the site formed at 350 ka or earlier.
4. The soil prisms in the Bt horizon near Soil Profile No. 3 were tilted toward the east when the right margin of the channel provided a free face. These pedogenic features are not evidence for tectonic movement there.

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Table 1. Description of Soil Profile No. 1 from Trench FT-1 at Station 0 + 43 excavated west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School, Beverly Hills, California. Abbreviations and definitions are given in Soil Survey Staff (1993; 1998; 1999).

Description of soil profile developed in Pleistocene alluvium by Glenn Borchardt, who measured and sampled the soil on January 12, 2012 at latitude N34^{o} 03.675' and longitude W118^{o} 24.767' at Station 0 + 43 in the south wall of Trench FT-1 at an elevation of 286'. Mediterranean climate with mean annual precipitation of 13.15"/yr (334 mm/yr) at Santa Monica from 1947 to 1979. Grass. Slope 2.7%. Aspect east. Excellent drainage. Water deep. The parent material is clay to gravel alluvium. Soil pH is moderately alkaline in the topsoil and mildly alkaline in the subsoil. Boring CB-2, taken at Station 44', passed through alluvium, encountering the San Pedro Formation at 78.7', which was at an elevation of 207.3'.

Horizon Depth, cm Description FT-1 Station 0 + 43

Ap 0-14 Fill that probably dates to construction of the school

A 14-34 Brown (7.5YR4/2m, 10YR5/3d) silty clay loam; coarse weak subangular blocky structure; slightly sticky and slightly plastic when wet, friable when moist, and very hard when dry; many fine to medium continuous random tubular pores; very few thin patchy clay films on sand grains and few thin clay films in pores; clear smooth boundary; pH 8.0; conductivity 400 uS; Sample No. 12B012.

2Bt 34-80 Brown (7.5YR4/2m, 10YR5/2d) clay with few fine prominent white mottles; coarse to medium moderate angular blocky structure; very sticky and very plastic when wet, firm when moist, and very hard when dry; few fine continuous random tubular pores; common thin patchy clay films on sand grains and common thin clay films on peds; gradual smooth boundary; pH 7.6; conductivity 750 uS; Sample No. 12B013. Level line at 60 cm.

3Bt1 80-114 Dark brown (10YR3/3m, 10YR6/3d) sandy clay with common fine prominent white mottles and very few fine distinct reddish yellow (7.5YR7/8md) mottles; medium to coarse weak subangular blocky structure; very sticky and very plastic when wet, firm when moist, and extremely hard when dry; very few fine continuous random tubular pores; common thin patchy clay films on sand grains and common thin clay films on peds; clear wavy boundary; pH 7.7; conductivity 880 uS; Sample No. 12B014.

3Bt2 114-209 Brown (7.5YR5/4 to 4/4m, 6/4 to 5/4d) clayey coarse sand with many medium to fine prominent white mottles; medium to coarse weak subangular blocky structure; sticky and plastic when wet, friable when moist, and very hard when dry; common fine to medium continuous random tubular and interstitial pores; many to common thin to medium thick clay films on sand grains, gravels and in pores; diffuse smooth boundary; pH 7.8; conductivity 880 uS; Sample No. 12B015.

4BCt 209-253 Grayish brown (10YR5/2m, 7/3d) sandy gravel with few fine distinct brown (10YR4/3md) and many medium distinct grayish brown (2.5Y5/2md) mottles on clasts; massive to fine weak subangular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and very hard when dry; common fine interstitial pores; common thin clay films in pores and on sand grains; common angular slate fragments; clear smooth boundary; pH 7.8; conductivity 760 uS; Sample No. 12B016.

5CB 253-271 Brown (7.5YR4/4m, 10YR5/4d) gravelly sand with many medium distinct grayish brown (2.5Y5/2md) mottles on clasts; medium weak subangular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and very hard when dry; many to common fine interstitial and continuous random tubular pores; many medium thick clay films in pores, interstices, and on sand grains; common subrounded slate fragments; clear smooth boundary; pH 7.8; conductivity 580 uS; Sample No. 12B017.

6CBt 271-345 Dark yellowish brown (10YR4/4m, 6/4d) gravel with many medium distinct grayish brown (2.5Y5/2md) mottles on clasts and common fine distinct very pale brown (10YR8/3md) and very few fine prominent red (2.5YR4/8md) mottles; massive structure; nonsticky and nonplastic when wet, very friable when moist, and very hard when dry; many fine interstitial and continuous random tubular pores; many medium thick clay films in pores, interstices, and on sand grains; diffuse smooth boundary; pH 7.6; conductivity 350 uS; Sample No. 12B018.

7CBt 345-406 Brown (10YR4/3m, 7/4d) gravelly sand with many medium distinct grayish brown (2.5Y5/2md) mottles on clasts and common fine distinct very pale brown (10YR8/3md) and very few fine prominent red (2.5YR4/8md) mottles; massive structure; nonsticky and nonplastic when wet, very friable when moist, and very hard when dry; many fine interstitial and continuous random tubular pores; few thin clay films in pores, interstices, and on sand grains; clear smooth boundary; pH 7.5; conductivity 270 uS; Sample No. 12B019. Level line at 390 cm.

8BCt 406-440+ Dark grayish brown (10YR4/2m, 5/2d) gravelly sand with many medium distinct grayish brown (2.5Y5/2md) mottles on clasts and common fine distinct very pale brown (10YR8/3md) and very few fine prominent red (2.5YR4/8md) mottles; massive structure; nonsticky and nonplastic when wet, very friable when moist, and very hard when dry; many fine interstitial and continuous random tubular pores; common thin to medium thick clay films in pores, interstices, and on sand grains; pH 7.7; conductivity 270 uS; Sample No. 12B020.

*ESTIMATED AGE:	t_o	=	80	ka
	t_b	=	0	ka
	t_d	=	80	ky

*Pedochronological estimates based on available information. All ages should be considered subject to ±50% variation unless otherwise indicated (Borchardt, 1992). Bold dates are absolute.
t_o = date when soil formation or aggradation began, ka
t_b = date when soil or strata was buried, ka
t_d = duration of soil development or aggradation, ky

Table 2. Description of Soil Profile No. 2 from Trench FT-2 at Station 0 + 85 excavated west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School, Beverly Hills, California. Abbreviations and definitions are given in Soil Survey Staff (1993; 1998; 1999)

Description of soil profile developed in Pleistocene alluvium by Glenn Borchardt, who measured and sampled the soil on January 13, 2012 at latitude N34^o 03.711' and longitude W118^o 24.706' at Station 0 + 85 in the north wall of Trench FT-2 at an elevation of 268'. Mediterranean climate with mean annual precipitation of 13.15"/yr (334 mm/yr) at Santa Monica from 1947 to 1979. Grass. Slope 9%. Aspect east. Excellent drainage. Water deep. Eroded. The parent material is silty clay to sandy gravel alluvium. Soil pH is neutral throughout.

Horizon   Depth, cm   Description   FT-2 Station 0 + 85

Ap   0-55   Fill that dates to construction of the school. Level at 50 cm.

ABtb1   55-90   Dark brown (10YR3/3m, 6/3d) gravelly clay loam with common fine distinct white and very few medium to fine distinct red mottles; fine to coarse strong subangular blocky structure; nonsticky and slightly plastic when wet, firm when moist, and very hard when dry; few fine roots; common fine continuous random tubular pores; common thin patchy clay films on sand grains and common thin clay films in pores; clear wavy boundary; pH 7.3; conductivity 190 uS; Sample No. 12B022. Eroded remnant of paleosol b1, with the 7'-thick Bt horizon described in core boring CB-3 at elevation 265.5' (ECI, 2012). At one time, it probably was buried by a correlative of the 80-ka relict paleosol described in Soil Profile No. 1.

2BCtb1   90-150   Brown (7.5YR4/4m, 5/4d) sandy gravel with common fine distinct white and very few medium to fine distinct gray mottles; fine weak subangular blocky structure; nonsticky and nonplastic when wet, very friable when moist, and very hard when dry; medium to few fine continuous random tubular and interstitial pores; many thin patchy clay films on sand grains; slate fragments; clear smooth boundary; pH 7.2; conductivity 160 uS; Sample No. 12B023.

3CBtb1   150-214   Brown (7.5YR5/4m, 10YR6/4d) silty clay; medium weak subangular blocky structure; sticky and plastic when wet, very friable when moist, and extremely hard when dry; few fine to medium continuous random tubular and interstitial pores; few medium thick patchy clay films in pores and interstices; abrupt smooth boundary; pH 7.3; conductivity 450 uS; Sample No. 12B024.

*ESTIMATED AGE:	t_o	=	150	ka
	t_b	=	80	ka
	t_d	=	70	ky

3Btb2   214-246   Brown (7.5YR5/4md) silty clay with few medium distinct light red (2.5YR6/8md) mottles; medium to coarse strong subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and extremely hard when dry; common fine continuous random tubular pores; many medium thick clay films in pores and on peds; abrupt wavy boundary; pH 7.3; conductivity 310 uS; Sample No. 12B025.

3BCtb2 246-277 Brown (10YR4/3m, 6/4d) silty clay with very few fine to medium distinct light red (2.5YR6/8md) mottles; medium to coarse moderate subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few fine continuous random tubular pores; few thin clay films on peds; few angular slate clasts; clear smooth boundary; pH 7.3; conductivity 210 uS; Sample No. 12B026. Level line at 231 cm.

4BCtb2 277-339 Brown (10YR4/3m, 7/4d) gravelly clayey sand with few medium distinct white mottles; coarse strong subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and extremely hard when dry; common to few fine continuous random tubular pores; common thin clay films on peds, and in pores and interstices; few angular slate clasts; abrupt wavy boundary; pH 7.2; conductivity 380 uS; Sample No. 12B027.

5CBtb2 339-381 Brown (10YR4/3m, 6/4d) silty clay loam; medium moderate subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and extremely hard when dry; many fine continuous random tubular pores; many thin to medium thick clay films on peds and in pores; clear smooth boundary; pH 7.1; conductivity 350 uS; Sample No. 12B028.

6CBtb2 381-440+ Brown (10YR4/3m, 6/4d) silty clay; medium moderate subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and very hard when dry; few fine continuous random tubular pores; few thin clay films in pores; pH 6.9; conductivity 290 uS; Sample No. 12B029.

*ESTIMATED AGE:	t_o	=	160	ka
	t_b	=	150	ka
	t_d	=	10	ky

*Pedochronological estimates based on available information. All ages should be considered subject to ±50% variation unless otherwise indicated (Borchardt, 1992). Bold dates are absolute.
t_o = date when soil formation or aggradation began, ka
t_b = date when soil or strata was buried, ka
t_d = duration of soil development or aggradation, ky

Table 3. Description of Soil Profile No. 3 from Trench FT-2 at Station 2 + 15 excavated west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School, Beverly Hills, California. Abbreviations and definitions are given in Soil Survey Staff (1993; 1998; 1999)

Description of soil profile developed in alluvium by Glenn Borchardt, who measured and sampled the soil on January 13, 2012 at latitude N34^o 03.722’ and longitude W118^o 24.687’ at Station 2 + 15 in the north wall of Trench FT-2 at an elevation of 251’. Mediterranean climate with mean annual precipitation of 13.15”/yr (334 mm/yr) at Santa Monica from 1947 to 1979. Grass. Slope 8%. Aspect east. Excellent drainage. Water deep. The parent material is clay to gravelly sandy clay alluvium. Soil pH is neutral throughout.

Horizon	Depth, cm	Description	FT-2 Station 2 + 15

Ap 0-30 Fill that dates to construction of the school.

A 30-80 Very dark grayish brown (10YR3/2m, 5/2d) clay loam; medium to coarse strong subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and very hard when dry; few fine to medium roots; few fine to medium continuous random tubular pores; clear smooth boundary; pH 6.7; conductivity 280 uS; Sample No. 12B032. Level line at 66 cm.

B 80-110 Dark grayish brown (10YR4/2m, 5/2d) sandy clay with common fine to medium faint gray (10YR5/1) mottles; medium strong subangular blocky structure; sticky and plastic when wet, very friable when moist, and extremely hard when dry; few fine roots; few fine to medium continuous random tubular pores; diffuse smooth boundary; pH 6.7; conductivity 280 uS; Sample No. 12B033.

2B 110-206 Dark brown (10YR3/3m, 5/2d) gravelly sandy clay with common fine to medium distinct gray (10YR5/1) and few fine distinct white mottles; coarse strong subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and extremely hard when dry; many fine continuous random tubular pores; few thin clay films in pores and on sand grains; diffuse wavy boundary; pH 6.8; conductivity 440 uS; Sample No. 12B034.

2BC 206-261 Dark yellowish brown (10YR4/4m, 5/4d) sandy clay; fine moderate subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few fine continuous random tubular pores; few thin patchy clay films on sand grains; diffuse wavy boundary; pH 6.9; conductivity 660 uS; Sample No. 12B035.

*ESTIMATED AGE:	t_o	=	41	ka
	t_b	=	0	ka
	t_d	=	41	ky

[Note that channel erosion before 41 ka has removed overlying paleosols b1, b2, and b3.]

2CBtb3 261-290 Brown (10YR5/3m, 6/4d) sandy clay; coarse to medium strong subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; many fine continuous random tubular pores; common thin clay films in pores and on peds; clear smooth boundary; pH 6.7; conductivity 930 uS; Sample No. 12B036. Former Ab horizon overprinted by pedogenesis after channel cutting removed the relict paleosol.

2Btb3 290-359 Grayish brown (10YR5/2m, 6/3d) clay with slate clasts and a 1 X 3 cm rectangular quartz clast; medium strong angular blocky structure; very sticky and very plastic when wet, very friable when moist, and very hard when dry; common fine continuous random tubular pores; common thin clay films in pores and on peds; clear wavy boundary; pH 6.8; conductivity 1030 uS; Sample No. 12B037. [Surface of horizon at elevation 241.5'.]

2CBtb3 359-429 Dark brown to dark yellowish brown (10YR4/3m to 3/4m, 6/4d) clay to gravelly clay with gray and white mottles due to slate and subrounded quartz clasts to 4 cm; medium moderate subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; common fine continuous random tubular pores; common thin clay films in pores and on peds and sand grains; clear wavy boundary; pH 6.7; conductivity 1030 uS; Sample No. 12B038.

2CBtb3 429-455+ Brown (10YR4/3m, 6/4d) clay with gray mottles due to slate; medium strong subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; common fine continuous random tubular pores; common thin clay films in pores and on sand grains; pH 6.8; conductivity 1160 uS; Sample No. 12B039.

*ESTIMATED AGE:	t_o	=	230	ka
	t_b	=	160	ka
	t_d	=	70	ky

*Pedochronological estimates based on available information. All ages should be considered subject to $\pm$50% variation unless otherwise indicated (Borchardt, 1992). Bold dates are absolute.
t_o = date when soil formation or aggradation began, ka
t_b = date when soil or strata was buried, ka
t_d = duration of soil development or aggradation, ky

Table 4. Description of Soil Profile No. 4 from Trench FT-2 at Station 2 + 80 excavated west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School, Beverly Hills, California. Abbreviations and definitions are given in Soil Survey Staff (1993; 1998; 1999).

Description of soil profile developed in alluvium by Glenn Borchardt, who measured and sampled the soil on February 1, 2012 at latitude N34^{o} 03.728' and longitude W118^{o} 24.678' at Station 2 + 80 in the north wall of Trench FT-2 at an elevation of 249'. Mediterranean climate with mean annual precipitation of 13.15"/yr (334 mm/yr) at Santa Monica from 1947 to 1979. Grass. Slope 3%. Aspect east. Excellent drainage. Water deep. The parent material is clayey sand to gravelly sand alluvium. Soil pH is neutral to moderately alkaline.

Horizon Depth, cm Description FT-2 Station 2 + 80

Ap 0-25 Very dark grayish brown (10YR3/2m, 5/2d) gravelly silty clay; fine strong subangular blocky structure; sticky and plastic when wet, very friable when moist, and extremely hard when dry; common fine roots; many fine continuous random tubular pores; abrupt smooth boundary; pH 7.7; conductivity 520 uS; Sample No. 12B081. Fill that probably dates to school construction.

A1 25-63 Dark brown (10YR3/3m, 5/3d) silty clay loam; coarse strong subangular blocky structure; sticky and plastic when wet, very friable when moist, and extremely hard when dry; few fine roots; few fine continuous random tubular pores; few thin clay films in pores and interstices; diffuse smooth boundary; pH 7.2; conductivity 240 uS; Sample No. 12B082a.

A2 63-127 Dark brown (10YR3/3m, 5/3d) sandy loam; medium strong granular structure; slightly sticky and slightly plastic when wet, very friable when moist, and very hard when dry; few fine roots; common fine continuous random tubular pores; diffuse smooth boundary; pH 7.4; conductivity 290 uS; Sample No. 12B082b.

B1t 127-189 Dark brown (10YR3/3m, 5/2d) silty clay loam; medium strong granular structure; sticky and plastic when wet, very friable when moist, and hard to very hard when dry; few fine continuous random tubular pores; few thin clay films in pores and interstices and bridging sand grains; abrupt smooth boundary; pH 7.4; conductivity 390 uS; Sample No. 12B082c.

B2t 189-222 Brown (10YR4/3m, 5/3d) gravelly sandy clay loam; medium moderate subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; many fine continuous random tubular pores; common thin patchy clay films bridging sand grains; abrupt smooth boundary; pH 7.9; conductivity 230 uS; Sample No. 12B083.

*ESTIMATED AGE:	t_o	=	6	ka
	t_b	=	0	ka
	t_d	=	6	ky

Btb 222-276 Brown (10YR4/3m, 6/3d) clay with common fine distinct white mottles; medium strong subangular blocky to prismatic structure; very sticky and very plastic when wet, firm when moist, and extremely hard when dry; many fine continuous random tubular pores; many thin to medium thick continuous clay films bridging sand grains and coating pores, peds, and angular slate clasts to 2 cm; diffuse wavy boundary; pH 7.6; conductivity 300 uS; Sample No. 12B084. Level line at 239 cm.

BCtb 276-336 Brown (10YR5/3m, 6/3d) sandy clay with common fine distinct white mottles; medium moderate angular to subangular blocky structure; very sticky and very plastic when wet, friable when moist, and very hard when dry; many fine to medium continuous random tubular pores; few thin to medium thick continuous clay films bridging sand grains and coating pores, peds, and angular slate clasts to 2 cm; abrupt smooth boundary; pH 7.8; conductivity 420 uS; Sample No. 12B085.

2CBtb 336-388 Grayish brown (10YR5/2m, 6/3d) clayey sand with few fine distinct white mottles; massive to fine weak subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; many fine to medium continuous random tubular pores; few thin to medium thick continuous clay films on bridging sand grains and coating pores, peds, and angular to subrounded slate clasts to 3 cm; abrupt smooth boundary; pH 7.6; conductivity 180 uS; Sample No. 12B086. Level at 388 cm.

3Cb 388-430 Grayish brown (10YR5/2m, 6/3d) gravelly sand; massive; nonsticky and nonplastic when wet, soft when moist, and loose when dry; many fine interstitial pores; abrupt smooth boundary; pH 7.4; conductivity 200 uS; Sample No. 12B087.

4Cb 430-440+ Brown (10YR5/3m, 6/3d) light clayey sand; massive to fine weak subangular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and loose when dry; many fine interstitial pores; pH 7.4; conductivity 170 uS; Sample No. 12B088.

*ESTIMATED AGE:	t_o	=	41	ka
	t_b	=	6	ka
	t_d	=	35	ky

*Pedochronological estimates based on available information. All ages should be considered subject to ±50% variation unless otherwise indicated (Borchardt, 1992). Bold dates are absolute.
t_o = date when soil formation or aggradation began, ka
t_b = date when soil or strata was buried, ka
t_d = duration of soil development or aggradation, ky

Table 5. Description of Soil Profile No. 5 from Trench FT-3 at Station 0 + 57 excavated west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School, Beverly Hills, California. Abbreviations and definitions are given in Soil Survey Staff (1993; 1998; 1999).

Description of soil profile developed in alluvium by Glenn Borchardt, who measured and sampled the soil on February 3, 2012 at latitude N34^{o} 03.633’ and longitude W118^{o} 24.715’ at Station 0 + 57 in the north wall of Trench FT-3 at an elevation of 283’. Mediterranean climate with mean annual precipitation of 13.15”/yr (334 mm/yr) at Santa Monica from 1947 to 1979. 10 cm asphalt over 15 cm of road base. Slope 1%. Aspect east. Excellent drainage. Water deep. The parent material is clayey sand to gravel alluvium. Soil pH is neutral.

Horizon	Depth, cm	Description	FT-3 Station 0 + 57

BCt1 0-94 Reddish brown (5YR4/4m, 7.5YR6/4d) gravelly clayey sand with many fine distinct white mottles; medium moderate subangular blocky to platy structure; sticky and plastic when wet, very friable when moist, and extremely hard when dry; many fine interstitial and few fine continuous random tubular pores; many medium thick clay films in interstitial pores and bridging sand grains; diffuse smooth boundary; pH 7.3; conductivity 1020 uS; Sample No. 12B091.

BCt2 94-129 Reddish brown (5YR4/4m, 7.5YR5/4d) sand with many fine distinct white mottles; massive to fine weak subangular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and loose when dry; many fine interstitial and few fine continuous random tubular pores; many medium thick clay films in interstitial pores and bridging sand grains; abrupt wavy boundary; pH 7.4; conductivity 740 uS; Sample No. 12B092.

2BCt 139-143 Brown (10YR5/3m, 6/4d) gravel with many fine distinct white mottles; massive structure; nonsticky and nonplastic when wet, soft when moist, and very hard when dry; many fine interstitial and few fine continuous random tubular pores; many medium thick clay films in interstitial pores and bridging sand grains and coating angular slate clasts to 3 cm; abrupt wavy boundary; pH 7.3; conductivity 840 uS; Sample No. 12B093.

3BCt 143-312 Brown (7.5YR4/4m, 10YR6/4d) sandy gravel with many fine distinct white mottles; massive structure; slightly sticky and slightly plastic when wet, very friable when moist, and very hard when dry; many fine interstitial and few fine continuous random tubular pores; many medium thick to thick clay films in interstitial pores and bridging sand grains and coating angular slate clasts to 2 cm; abrupt wavy boundary; pH 6.9; conductivity 1410 uS; Sample No. 12B094. Level line at 158 cm.

4CBt 312-440+ Yellowish brown (10YR5/4m, 6/4d) clayey sand; massive to medium weak subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; many fine interstitial pores; pH 7.3; conductivity 1020 uS; Sample No. 12B095.

*ESTIMATED AGE:	t_o	=	80	ka
	t_b	=	0	ka
	t_d	=	80	ky

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*Pedochronological estimates based on available information. All ages should be considered subject to $\pm$50% variation unless otherwise indicated (Borchardt, 1992). Bold dates are absolute.
t_o = date when soil formation or aggradation began, ka
t_b = date when soil or strata was buried, ka
t_d = duration of soil development or aggradation, ky

Table 6. Description of Soil Profile No. 6 from core boring CB-13 taken north of Beverly Hills Description of soil profile developed in Pleistocene alluvium by Glenn Borchardt, who measured and sampled the soil from core boxes on February 24, 2012. The core was drilled at an elevation of 264’ at latitude N34^o 03.750 and longitude W118^o 24.817’ on February 17, 2012. Mediterranean climate with mean annual precipitation of 13.15”/yr (334 mm/yr) at Santa Monica from 1947 to 1979. Pepper trees and other ornamentals. Slope 0.5%. Aspect east. Moderate drainage. Water deep. The parent material is clay to gravelly sand alluvium. Soil pH is moderately alkaline in the topsoil, neutral in intervening horizons, and moderately alkaline at depth.

Horizon Depth, cm Description Core Boring CB-13

A/Bt? 0-153 Based on the existence of the CBt horizon below, I speculate that the missing upper 153 cm may have had a 30-cm thick A and a Bt horizon up to 123-cm thick.

CBt 153-170 Dark brown (10YR3/3m, 6/3d) silty clay loam with few fine distinct black mottles due to mangans; medium moderate angular to subangular blocky structure; sticky and plastic when wet, firm when moist, and extremely hard when dry; very few fine continuous random tubular pores; few thin clay films in interstices; few very fine vermiculite flakes; clear smooth boundary; pH 7.9; conductivity 190 uS; Sample No. 12B211.

*ESTIMATED AGE:	t_o	=	41	ka
	t_b	=	0	ka
	t_d	=	41	ky

2Btb1 170-195 Dark brown (10YR3/3m, 7/3d) clay with few fine to medium distinct black mottles due to mangans and few fine to medium distinct yellow (10YR8/6d) mottles due to goethite; medium moderate subangular to angular blocky structure; very sticky and very plastic when wet, firm when moist, and extremely hard when dry; very few fine discontinuous random tubular pores; few thin patchy clay films in interstices and coating clasts; gradual smooth boundary; pH 7.5; conductivity 430 uS; Sample No. 12B212.

2CBtb1 195-458 Dark grayish brown (10YR4/2m, 6/3d) clay with few fine to medium distinct black mottles due to mangans and few fine to medium distinct yellow (10YR8/6d) mottles due to goethite; medium moderate subangular to angular blocky structure; sticky and plastic when wet, firm when moist, and extremely hard when dry; very few very fine discontinuous random tubular pores; few thin patchy clay films in interstices and coating clasts concentrated in 1-cm thick horizontal lamellae; pH 7.3; conductivity 490 uS; Sample No. 12B213.

*ESTIMATED AGE:	t_o	=	49	ka
	t_b	=	41	ka
	t_d	=	8	ky

2Btb2 458-505 Grayish brown (2.5Y5/2m, 6/2d) clay with common medium prominent white mottles due to calcite coatings on peds; medium moderate subangular to angular blocky structure; very sticky and very plastic when wet, firm when moist, and extremely hard when dry; very few very fine discontinuous random tubular pores; few thin patchy clay films in interstices and coating clasts concentrated in 1-cm thick horizontal lamellae; violent effervescence of calcite; gradual smooth boundary; pH 7.5; conductivity 580 uS; Sample No. 12B214.

2CBtb2 505-762 Dark grayish brown (2.5Y4/2m, 7/4d) clay to gravelly silty clay loam with common medium distinct yellowish brown (10YR5/6m) 1-cm thick lamellae due to goethite in sandy layers; medium moderate subangular to angular blocky structure; very sticky and very plastic when wet, firm to very friable when moist, and extremely hard when dry; few very fine discontinuous random tubular pores; common thin to medium thick clay films in interstices within 1-cm thick clayey lamellae, giving varved appearance; clear smooth boundary; pH 7.4; conductivity 300 uS; Sample No. 12B215 from 530, 560, and 570 cm.

*ESTIMATED AGE:	t_o	=	65	ka
	t_b	=	49	ka
	t_d	=	16	ky

2Btb3 762-830 Brown (7.5YR4/4m, 5/4d) clay with common medium distinct dark grayish brown (2.5Y4/2m) reworked clayey peds; medium moderate angular to subangular blocky structure; sticky and plastic when wet, firm when moist, and very hard when dry; many very fine continuous random tubular pores; common thin to medium thick clay films in interstices and pores and coating peds and clasts other than quartz, which have only patchy films; clear smooth boundary; pH 7.3; conductivity 210 uS; Sample No. 12B216. [Surface of horizon at 241’ elevation.]

2CBtb3 830-970 Brown (10YR4/3m, 5/3d) gravelly clay with common medium distinct dark grayish brown (2.5Y4/2m) reworked clayey peds; medium moderate subangular to angular blocky structure; very sticky and very plastic when wet, firm when moist, and extremely hard when dry; common very fine continuous random tubular pores; few common thin to medium thick clay films in interstices and coating peds and platy white clasts with patchy clay films; fine vermiculite flakes; pH 7.2; conductivity 200 uS; Sample No. 12B217. [Surface of horizon at 237’ elevation.]

3CBb3 970-1100 Gray, brown, pink, and white gravel; massive structure; nonsticky and nonplastic when wet, very friable when moist, and soft when dry; many intersticial pores; few thin clay films bridging sand grains on the bottoms of some gray slate clasts; pH 7.2; conductivity 110 uS; Sample No. 12B218.

4CBb3 1100-1980 Silty clay loam; varved.

*ESTIMATED AGE:	t_o	=	134	ka
	t_b	=	65	ka
	t_d	=	69	ky

4Btkb4 1980-2000 Brown (10YR4/3m, 5/3d) clay with few medium prominent light brownish gray (10YR6/2d) mottles due to reworked clay peds and few fine distinct yellow (10YR7/8d) mottles due to goethite and few fine predominant white mottles due to calcite filaments and coatings following common thin to medium thick clay films in interstices, coating peds, and clasts; medium strong subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and very hard when dry; few fine continuous to discontinuous random tubular pores; calcite has violent effervescence; abrupt smooth boundary; pH 7.5; conductivity 430 uS; abrupt smooth boundary; Sample No. 12B219. [Surface at elevation 200']

4BCtb4 2000-2286 Brown (10YR4/3m, 5/3d) clayey gravelly sand with common fine to medium distinct light brownish gray (10YR6/2d) mottles due to reworked clay peds; medium moderate subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few fine continuous to discontinuous random tubular pores; few thin clay films in interstices and patchy clay films on clasts other than quartz; <2 cm subrounded slate clasts; slight effervescence of few calcite filaments; pH 7.8; conductivity 220 uS; Sample No. 12B220.

*ESTIMATED AGE:	t_o	=	141	ka
	t_b	=	134	ka
	t_d	=	7	ky

4Btb5 2286-2315 Brown (10YR4.5/3m, 6.5/3d) very fine sand with few fine distinct white mottles due to calcite filaments; massive structure; nonsticky and nonplastic when wet, very friable when moist, and very hard when dry; few fine continuous to discontinuous random tubular pores; very few thin clay films in interstices and on clasts; <2 cm subrounded slate clasts; slight effervescence of few calcite filaments; gradual smooth boundary; pH 7.9; conductivity 310 uS; Sample No. 12B221.

4BCtb5 2315-2450 Brown (7.5YR4/2m, 6/2d) clayey very fine sand with common fine to medium prominent white mottles due to calcite filaments and light brownish gray (10YR6/2d) mottles due to reworked peds; medium moderate subangular to angular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and very hard when dry; few fine continuous random tubular pores; very few thin clay films in interstices; <2 cm subrounded slate clasts; slight effervescence of few calcite filaments; gradual smooth boundary; pH 8.0; conductivity 340 uS; Sample No. 12B222.

4BCtb5 2450- Dark grayish brown (2.5Y4/2m, 6/2d) clay to silty clay with very few fine distinct white mottles due to calcite filaments; medium moderate subangular to angular blocky structure; very sticky and very plastic when wet, very friable when moist, and extremely hard when dry; few fine continuous random tubular pores; very few thin clay films in interstices; gradual smooth boundary; pH 8.0; conductivity 350 uS; Sample No. 12B223. [Duplicate: pH 7.9; conductivity 370 uS; Sample No. 12B224.]

*ESTIMATED AGE:	t_o	=	151	ka
	t_b	=	141	ka
	t_d	=	10	ky

Non-pedogenic section:

Feet	cm	
80.5	3368	Gravelly sandy clay; pH 7.8; conductivity 200 uS; Sample No. 12B230.
110.5	3871	Sandy silty to clay; pH 7.8; conductivity 350 uS; Sample No. 12B234.
127	4023	Silty sand with calcite; pH 7.9; conductivity 240 uS; Sample No. 12B235.
137	4176	Sandy clay with calcite; pH 7.9; conductivity 410 uS; Sample No. 12B236.
142	4328	Olive gray sandy clay with calcite; pH 8.0; conductivity 390 uS; Sample No. 12B237.
156	4755	Dark gray clay with calcite; pH 7.9; conductivity 680 uS; Sample No. 12B240.

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*Pedochronological estimates based on available information. In this case, Bt horizon development was assumed to occur at the rate of 10 ky/30 cm. Bt horizons did not form when the marsh was flooded. Thus, this estimate is considerably less than half the true age of the section. All ages should be considered subject to ±50% variation unless otherwise indicated (Borchardt, 2010). Bold dates are absolute.

t_o = date when soil formation or aggradation began, ka

t_b = date when soil or strata was buried, ka

t_d = duration of soil development or aggradation, ky

Figure 1. Upper portion of Soil Profile No. 1 at Station 0 + 43 in the south wall of Trench FT-1 west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School.

Figure 2. Lower portion of Soil Profile No. 1 at Station 0 + 43 in the south wall of Trench FT-1 west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School. Clay film development reaches over 440 cm in this profile.

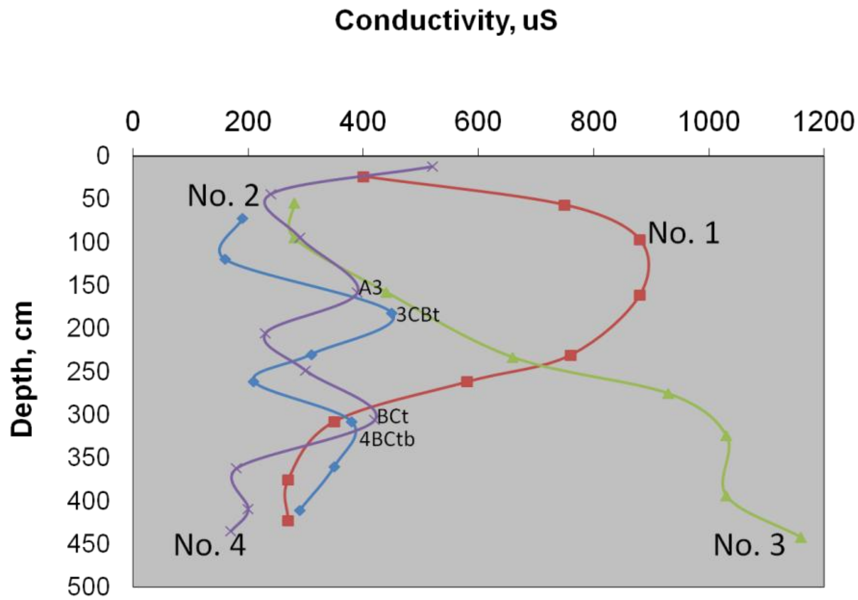

Figure 3. Depth functions for conductivity in Soil Profile Nos. 1, 2, 3, and 4 west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School, Beverly Hills, California. The high salt content in the Bt horizons of No. 1 probably reflects the marine environment and low precipitation that occurs at present. During the Pleistocene, the Bt horizons would have had a much lower salt content due to leaching. Leached salts normally tend to accumulated immediately beneath the "wetting front," which is normally the base of the B horizon. The low conductivity of the 3BCtb horizon of No. 2 reflects the leaching of salts during the initial development of this paleosol.

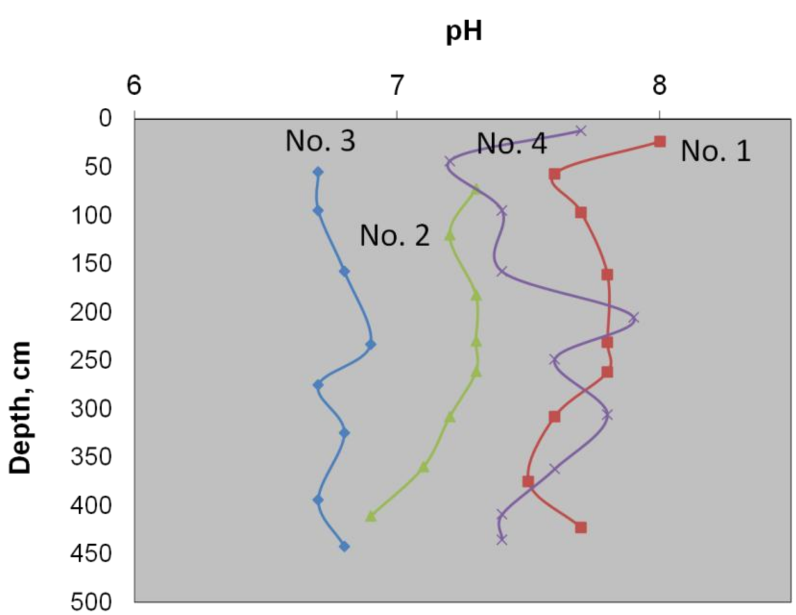

Figure 4. Soil pH of the four soil profiles. Note that Soil Profile Nos. 2 and 3 are more acidic than either the oldest (No. 1) or the youngest (No. 4).

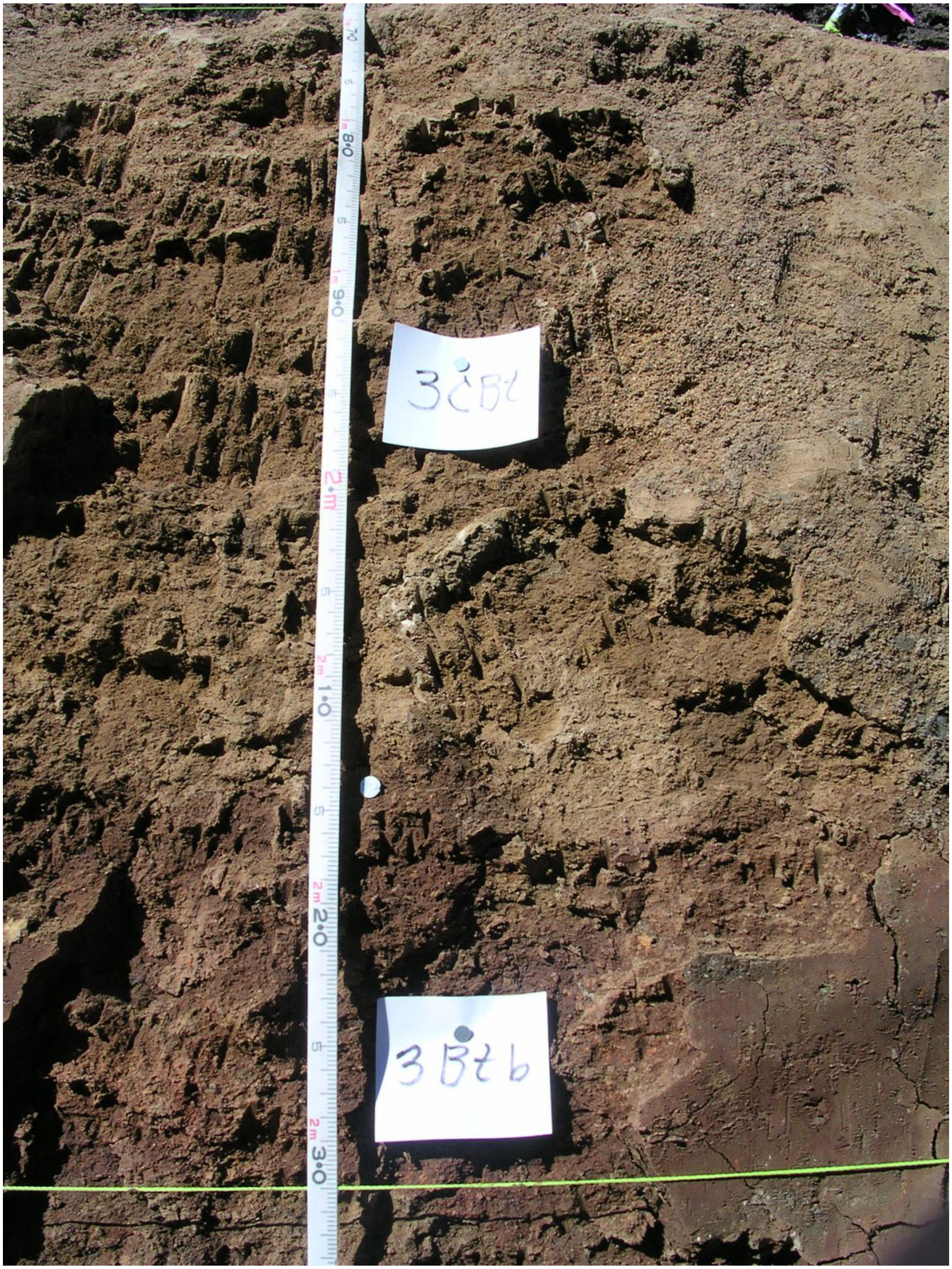

Figure 5. A reddish moderately well developed paleosol (horizon 3Btb) exists beneath the 214-cm depth in Soil Profile No. 2 at Station 0 + 85 in Trench FT-2 west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School. View N.

Figure 6. Channel fill next to the reddish paleosol that was in Soil Paleosol No. 2 (vertical tape) in the north wall of Trench FT-2.

Figure 7. Tilted prismatic and angular blocky soil structure within the paleosol on the south wall of Trench FT-2 across from Soil Profile No. 3. The tilting is a result of soil creep that occurred when an active channel existed immediately to the east.

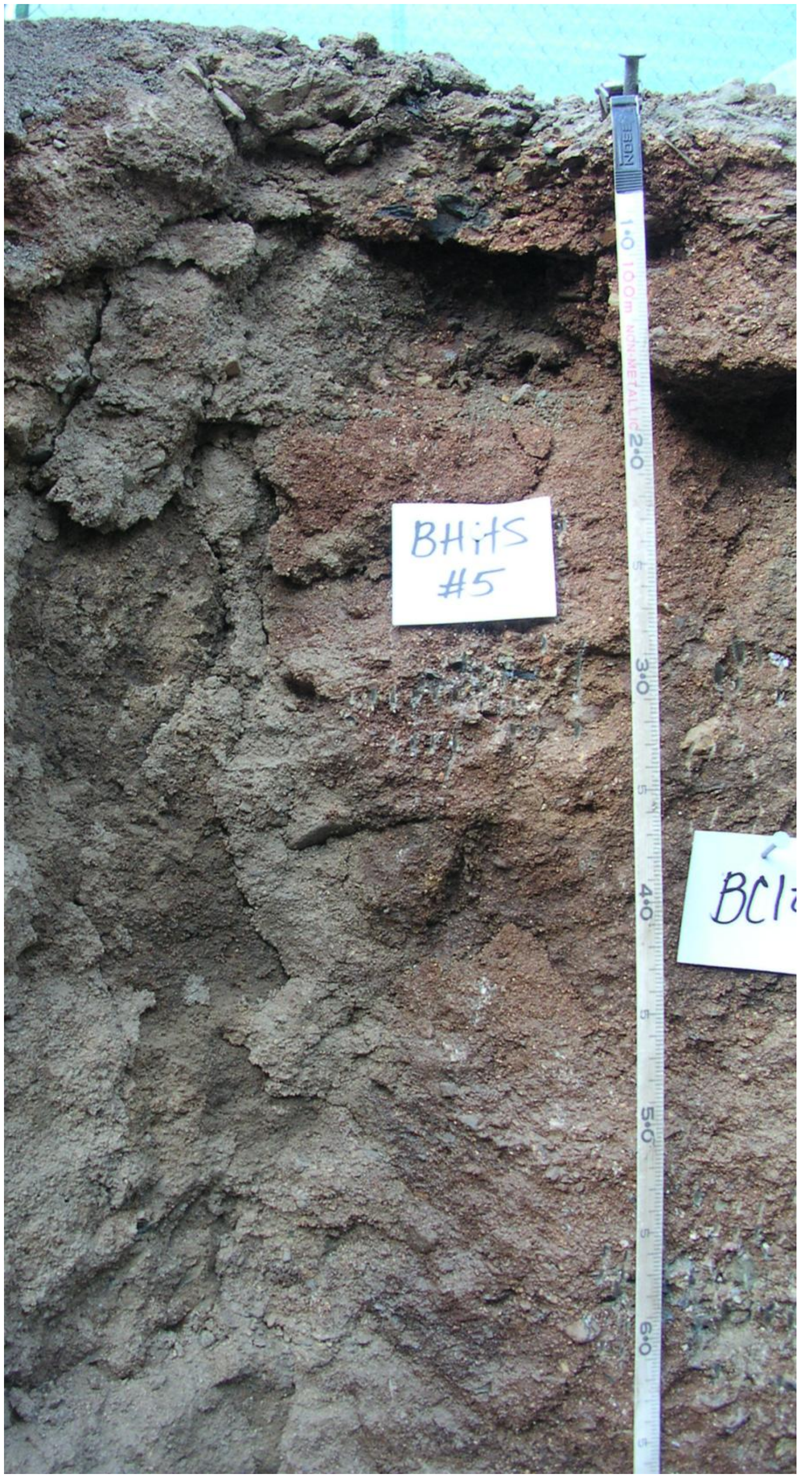

Figure 8. Reddish brown (5YR4/4m) upper portion of Soil Profile No. 5 in Trench FT-3 sampled adjacent to the brown (10YR5/3m) sandy soil tongue.

Figure 9. Varves in Soil Profile No. 6 (core boring CB-13) reflecting seasonal redox conditions produced when high rainfall formed a marsh at this locality. The term "varve," once used exclusively for glacial lakes, is now used for other fluctuating fresh-water environments.

SOILS GLOSSARY

AGE. Elapsed time in calendar years. Because the cosmic production of C-14 has varied during the Quaternary, radiocarbon years (expressed as ky B.P.) must be corrected by using tree-ring and other data. Abbreviations used for corrected ages are: ka (kilo anno or years in thousands) or Ma (millions of years). Abbreviations used for intervals are: yr (years), ky (thousands of years). radiocarbon ages = yr B.P. Calibrated ages are calculated from process assumptions, relative ages fit in a sequence, and correlated ages refer to a matching unit. (See also yr B.P., HOLOCENE, PLEISTOCENE, QUATERNARY, PEDOCHRONOLOGY).

AGGRADATION. A modification of the earth's surface in the direction of uniformity of grade by deposition.

ALKALI (SODIC) SOIL. A soil having so high a degree of alkalinity (pH 8.5 or higher), or so high a percentage of exchangeable sodium (15 % or more of the total exchangeable bases), or both, that plant growth is restricted.

ALKALINE SOIL. Any soil that has a pH greater than 7.3. (See Reaction, Soil.)

ANGULAR ORPHANS. Angular fragments separated from weathered, well-rounded cobbles in colluvium derived from conglomerate.

ARGILLAN. (See Clay Film.)

ARGILLIC horizon. A horizon containing clay either translocated from above or formed in place through pedogenesis.

ALLUVIATION. The process of building up of sediments by a stream at places where stream velocity is decreased. The coarsest particles settle first and the finest particles settle last.

ANOXIC. (See also GLEYED SOIL). A soil having a low redox potential.

AQUICLUDE. A saturated body of sediment or rock that is incapable of transmitting significant quantities of water under ordinary hydraulic gradients.

AQUITARD. A body of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs but may serve as a storage unit for groundwater.

ATTERBERG LIMITS. The moisture content at which a soil passes from a semi-solid to a plastic state (plastic limit, PL) and from a plastic to a liquid state (liquid limit, LL). The plasticity index (PI) is the numerical difference between the LL and the PL.

BEDROCK. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

BISEQUUM. Two soils in vertical sequence, each soil containing an eluvial horizon and its underlying B horizon.

BOUDIN, BOUDINAGE. From a French word for sausage, describes the way that layers of rock break up under extension. Imagine the hand, fingers together, flat on the table, encased in soft clay and being squeezed from above, as being like a layer of rock. As the spreading clay moves the fingers (sausages) apart, the most mobile rock fractions are drawn or squeezed into the developing gaps.

BURIED SOIL. A developed soil that was once exposed but is now overlain by a more recently formed soil.

CALCAREOUS SOIL. A soil containing enough calcium carbonate (commonly with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid. A soil having measurable amounts of calcium carbonate or magnesium carbonate.

CARBONATE MORPHOLOGY STAGES. Descriptive classes of calcite precipitation indicating increasing pedogenesis over time:

	Stage	% $CaCO_3$
I	Bk horizon with few filaments and coatings	<10
I+	Bk with common filaments and continuous clast coatings	<10
II	Bk with continuous clast coatings, white masses, few nodules	>10
II+	Bk as above, but matrix is completely whitened, common nodules	>15
III	K horizon that is 90% white, many nodules	>20
III+	K that is completely plugged	>40
IV	K as above, but upper part cemented and has weak platy structure	>50
V	K same as above, but laminar layer is strong with incipient brecciation	>50
VI	K brecciation and recementation, as well as pisoliths, are common	>50

CATENA. A sequence of soils of about the same age, derived from similar parent material and forming under similar climatic conditions, but having different characteristics due to variation in relief and drainage. (See also TOPOSEQUENCE.)

CEC. Cation exchange capacity. The amount of negative charge balanced by positively charged ions (cations) that are exchangeable by other cations in solution (meq/100 g soil = cmol(+)/kg soil).

CLAY. As a soil separate, the mineral soil particles are less than 0.002 mm in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

CLAY FILM. A coating of oriented clay on the surface of a sand grain, pebble, soil aggregate, or ped. Clay films also line pores or root channels and bridge sand grains. Frequency classification is based on the percent of the ped faces and/or pores that contain films: very few--<5%; few--5-25%; common--25-50%; many--50-90%; and continuous--90-100%. Thickness classification is based on visibility of sand grains: thin--very fine sand grains standout; moderately thick--very fine sand grains impart microrelief to film; thick--fine sand grains enveloped by clay and films visible without magnification. Synonyms: clay skin, clay coat, argillan, illuviation cutan.

CLAY LAMELLAE. Thin, generally wavy bands that appear as multiple micro-Bt horizons at the base of the solum in sandy Holocene deposits. The lamellae generally are 1-3 cm in thickness and 5 to 30 cm apart. There may be two to six or more clay lamellae comprising the Bt horizon of such a soil.

COBBLE. Rounded or partially rounded fragments of rock ranging from 7.5 to 25 cm in diameter.

COLLUVIUM. Any loose mass of soil or rock fragments that moves downslope largely by the force of gravity. Usually it is thicker at the base of the slope.

COLLUVIUM-FILLED SWALE. The prefailure topography of the source area of a debris flow.

COMPARATIVE PEDOLOGY. The comparison of soils, particularly through examination of features known to evolve through time.

CONCRETIONS. Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrated compounds or cemented soil grains. The composition of most concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are common compounds in concretions.

CONDUCTIVITY. The ability of a soil solution to conduct electricity, generally expressed as the reciprocal of the electrical resistivity. Electrical conductance is the reciprocal of the resistance (1/R = 1/ohm = ohm^{-1} = mho [reverse of ohm] = siemens = S), while electrical conductivity is the reciprocal of the electrical resistivity (EC = 1/r = 1/ohm-cm = mho/cm = S/cm or mmho/cm = dS/m). EC, expressed as uS/cm, is equivalent to the ppm of salt in solution when multiplied by 0.640. Pure rain water has an EC of 0, standard 0.01 N KCl is 1411.8 uS at 25C, and the growth of salt-sensitive crops is restricted in soils having saturation extracts with an EC greater than 2,000 uS/cm. Measurements in soils are usually performed on 1:1 suspensions containing one part by weight of soil and one part by weight of distilled water.

CONSISTENCE, SOIL. The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are --

Loose.--Noncoherent when dry or moist; does not hold together in a mass.

Friable.--When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm.--When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.--When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

Sticky.--When wet, adheres to other material, and tends to stretch somewhat and pull apart, rather than to pull free from other material.

Hard.--When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.--When dry, breaks into powder or individual grains under very slight pressure.

Cemented.--Hard and brittle; little affected by moistening.

CTPOT. Easily remembered acronym for climate, topography, parent material, organisms, and time; the five factors of soil formation.

CUMULIC. A soil horizon that has undergone aggradation coincident with its active development.

CUTAN. (See Clay Film.)

DEBRIS FLOW. Incoherent or broken masses of rock, soil, and other debris that move downslope in a manner similar to a viscous fluid.

DEBRIS SLOPE. A constant slope with debris on it from the free face above.

DEGRADATION. A modification of the earth's surface by erosion.

DURIPAN. A subsurface soil horizon that is cemented by illuvial silica, generally deposited as opal or microcrystalline silica, to the degree that less than 50 percent of the volume of air-dry fragments will slake in water or HCl.

ELUVIATION. The removal of soluble material and solid particles, mostly clay and humus, from a soil horizon by percolating water.

EOLIAN. Deposits laid down by the wind, landforms eroded by the wind, or structures such as ripple marks made by the wind.

FAULT-LINE SCARP. A scarp that has been produced by differential erosion along an old fault line.

FAULTSLIDE. A landslide that shows physical evidence of its interaction with a fault.

FIRST-ORDER DRAINAGE. The most upstream, field-discernible concavity that conducts water and sediments to lower parts of a watershed.

FLOOD PLAIN. A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

FOSSIL FISSURE. A buried rectilinear chamber associated with extension due to ground movement. The chamber must be oriented along the strike of the shear and must have vertical and horizontal dimensions greater than its width. It must show no evidence of faunal activity and its walls may have silt or clay coatings indicative of frequent temporary saturation with ground water. May be mistaken for an animal burrow. Also known as a paleofissure.

FRIABILITY. Term for the ease with which soil crumbles. A friable soil is one that crumbles easily.

GENESIS, SOIL. The mode of origin of the soil. Refers especially to the processes or soil-forming factors responsible for the formation of the solum (A and B horizons) from the unconsolidated parent material.

GEOMORPHIC. Pertaining to the form of the surface features of the earth. Specifically, geomorphology is the analysis of landforms and their mode of origin.

GLEYED SOIL. A soil having one or more neutral gray horizons as a result of water logging and lack of oxygen. The term "gleyed" also designates gray horizons and horizons having yellow and gray mottles as a result of intermittent water logging.

GRAVEL. Rounded or angular fragments of rock 2 to 75 mm in diameter. Soil textures with >15% gravel have the prefix "gravelly" and those with >90% gravel have the suffix "gravel."

HIGHSTAND. The highest elevation reached by the ocean during an interglacial period.

HOLOCENE. The most recent epoch of geologic time, extending from 10 ka to the present.

HORIZON, SOIL. A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major soil horizons:

O horizon.--The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.

A horizon.--The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).

E horizon -- This eluvial horizon is light in color, lying beneath the A horizon and above the B horizon. It is made up mostly of sand and silt, having lost most of its clay and iron oxides through reduction, chelation, and translocation.

B horizon.--The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these.

C horizon.--The relatively unweathered material immediately beneath the solum. Included are sediment, saprolite, organic matter, and bedrock excavatable with a spade. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a number precedes the letter C.

R horizon.--Consolidated rock not excavatable with a spade. It may contain a few cracks filled with roots or clay or oxides. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

Major horizons may be further distinguished by applying prefix Arabic numbers to designate differences in parent materials as they are encountered (e.g., 2B, 2BC, 3C) or by applying suffix numerals to designate minor changes (e.g., B1, B2).

The following is from Soil Survey Staff (2006):

“Suffix Symbols

Lowercase letters are used as suffixes to designate specific kinds of master horizons and layers. The term “accumulation” is used in many of the definitions of such horizons to indicate that these horizons must contain more of the material in question than is presumed to have been present in the parent material. The suffix symbols and their meanings are as follows:

a Highly decomposed organic material

This symbol is used with O to indicate the most highly decomposed organic materials, which have a fiber content of less than 17 percent (by volume) after rubbing.

b Buried genetic horizon

This symbol is used in mineral soils to indicate identifiable buried horizons with major genetic features that were developed before burial. Genetic horizons may or may not have formed in the overlying material, which may be either like or unlike the assumed parent material of the buried soil. This symbol is not used in organic soils, nor is it used to separate an organic layer from a mineral layer.

c *Concretions or nodules*

This symbol indicates a significant accumulation of concretions or nodules. Cementation is required. The cementing agent commonly is iron, aluminum, manganese, or titanium. It cannot be silica, dolomite, calcite, or more soluble salts.

co *Coprogenous earth*

This symbol, used only with L, indicates a limnic layer of coprogenous earth (or sedimentary peat).

d *Physical root restriction*

This symbol indicates noncemented, root-restricting layers in natural or human-made sediments or materials. Examples are dense basal till, plowpans, and other mechanically compacted zones.

di *Diatomaceous earth*

This symbol, used only with L, indicates a limnic layer of diatomaceous earth.

e *Organic material of intermediate decomposition*

This symbol is used with O to indicate organic materials of intermediate decomposition. The fiber content of these materials is 17 to 40 percent (by volume) after rubbing.

f *Frozen soil or water*

This symbol indicates that a horizon or layer contains permanent ice. The symbol is not used for seasonally frozen layers or for dry permafrost.

ff *Dry permafrost*

This symbol indicates a horizon or layer that is continually colder than 0 oC and does not contain enough ice to be cemented by ice. This suffix is not used for horizons or layers that have a temperature warmer than 0 oC at some time of the year.

g *Strong gleying*

This symbol indicates either that iron has been reduced and removed during soil formation or that saturation with stagnant water has preserved it in a reduced state. Most of the affected layers have chroma of 2 or less, and many have redox concentrations. The low chroma can represent either the color of reduced iron or the color of uncoated sand and silt particles from which iron has been removed. The symbol g is not used for materials of low chroma that have no history of wetness, such as some slates or E horizons. If g is used with B, pedogenic change in addition to gleying is implied. If no other pedogenic change besides gleying has taken place, the horizon is designated Cg.

h *Illuvial accumulation of organic matter*

This symbol is used with B to indicate the accumulation of illuvial, amorphous, dispersible complexes of organic matter and sesquioxides if the sesquioxide component is dominated by aluminum but is present only in very small quantities. The organo-sesquioxide material coats sand and silt particles. In some horizons these coatings have coalesced, filled pores, and cemented the horizon. The symbol h is also used in combination with s as “Bhs” if the amount of the sesquioxide component is significant but the color value and chroma, moist, of the horizon are 3 or less.

i *Slightly decomposed organic material*

This symbol is used with O to indicate the least decomposed of the organic materials. The fiber content of these materials is 40 percent or more (by volume) after rubbing.

j *Accumulation of jarosite*

Jarosite is a potassium or iron sulfate mineral that is commonly an alteration product of pyrite that has been exposed to an oxidizing environment. Jarosite has hue of 2.5Y or yellower and normally has chroma of 6 or more, although chromas as low as 3 or 4 have been reported. [Note: No longer used to indicate “juvenile.”]

jj *Evidence of cryoturbation*

Evidence of cryoturbation includes irregular and broken horizon boundaries, sorted rock fragments, and organic soil materials existing as bodies and broken layers within and/or between mineral soil layers. The organic bodies and layers are most commonly at the contact between the active layer and the permafrost.

k *Accumulation of secondary carbonates*

This symbol indicates an accumulation of visible pedogenic calcium carbonate (less than 50 percent, by volume). Carbonate accumulations exist as carbonate filaments, coatings, masses, nodules, disseminated carbonate, or other forms.

kk *Engulfment of horizon by secondary carbonates*

This symbol indicates major accumulations of pedogenic calcium carbonate. The suffix kk is used when the soil fabric is plugged with fine grained pedogenic carbonate (50 percent or more, by volume) that exists as an essentially continuous medium. The suffix corresponds to the stage III plugged horizon or higher of the carbonate morphogenetic stages (Gile et al., 1966).

m *Cementation or induration*

This symbol indicates continuous or nearly continuous cementation. It is used only for horizons that are more than 90 percent cemented, although they may be fractured. The cemented layer is physically root-restrictive. The dominant cementing agent (or the two dominant ones) may be indicated by adding defined letter suffixes, singly or in pairs. The horizon suffix km indicates cementation by carbonates; qm, cementation by silica; sm, cementation by iron; ym, cementation by gypsum; kqm, cementation by lime and silica; and zm, cementation by salts more soluble than gypsum.

ma *Marl*

This symbol, used only with L, indicates a limnic layer of marl.

n *Accumulation of sodium*

This symbol indicates an accumulation of exchangeable sodium.

o *Residual accumulation of sesquioxides*

This symbol indicates a residual accumulation of sesquioxides.

p *Tillage or other disturbance*

This symbol indicates a disturbance of the surface layer by mechanical means, pasturing, or similar uses. A disturbed organic horizon is designated Op. A disturbed mineral horizon is designated Ap even though it is clearly a former E, B, or C horizon.

q *Accumulation of silica*

This symbol indicates an accumulation of secondary silica.

r *Weathered or soft bedrock*

This symbol is used with C to indicate cemented layers (moderately cemented or less cemented). Examples are weathered igneous rock and partly consolidated sandstone, siltstone, or slate. The excavation difficulty is low to high.

s *Illuvial accumulation of sesquioxides and organic matter*

This symbol is used with B to indicate an accumulation of illuvial, amorphous, dispersible complexes of organic matter and sesquioxides if both the organic-matter and sesquioxide components are significant and if either the color value or chroma, moist, of the horizon is 4 or more. The symbol is also used in combination with h as "Bhs" if both the organic-matter and sesquioxide components are significant and if the color value and chroma, moist, are 3 or less.

ss *Presence of slickensides*

This symbol indicates the presence of slickensides. Slickensides result directly from the swelling of clay minerals and shear failure, commonly at angles of 20 to 60 degrees above horizontal. They are indicators that other vertic characteristics, such as wedge-shaped peds and surface cracks, may be present.

t *Accumulation of silicate clay*

This symbol indicates an accumulation of silicate clay that either has formed *in situ* within a horizon or has been moved into the horizon by illuviation, or both. At least some part of the horizon should show evidence of clay accumulation either as coatings on surfaces of peds or in pores, as lamellae, or as bridges between mineral grains.

u *Presence of human-manufactured materials (artifacts)*

This symbol indicates the presence of manufactured artifacts that have been created or modified by humans, usually for a practical purpose in habitation, manufacturing, excavation, or construction activities. Examples of artifacts are processed wood products, liquid petroleum products, coal, combustion by-products, asphalt, fibers and fabrics, bricks, cinder blocks, concrete, plastic, glass, rubber, paper, cardboard, iron and steel, altered metals and minerals, sanitary and medical waste, garbage, and landfill waste.

v *Plinthite*

This symbol indicates the presence of iron-rich, humus-poor, reddish material that is firm or very firm when moist and hardens irreversibly when exposed to the atmosphere and to repeated wetting and drying.

w *Development of color or structure*

This symbol is used with B to indicate the development of color or structure, or both, with little or no apparent illuvial accumulation of material. It should not be used to indicate a transitional horizon.

x *Fragipan character*

This symbol indicates a genetically developed layer that has a combination of firmness and brittleness and commonly a higher bulk density than the adjacent layers. Some part of the layer is physically root-restrictive.

y *Accumulation of gypsum*

This symbol indicates an accumulation of gypsum.

z *Accumulation of salts more soluble than gypsum*

This symbol indicates an accumulation of salts that are more soluble than gypsum."

HUMUS. The well-decomposed, more or less stable part of the organic matter in mineral soils.

ILLUVIATION. The deposition by percolating water of solid particles, mostly clay or humus, within a soil horizon.

INTERFLUVE. The land lying between streams.

ISOCHRONOUS BOUNDARY. A gradational boundary between two sedimentary units indicating that they are approximately the same age. Opposed to a nonisochronous boundary, which by its abruptness indicates that it delineates units having significant age differences.

KROTOVINA. An animal burrow filled with soil.

LEACHING. The removal of soluble material from soil or other material by percolating water.

LOWSTAND. The lowest elevation reached by the ocean during a glacial period.

MANGAN. A thin coating of manganese oxide (cutan) on the surface of a sand grain, pebble, soil aggregate, or ped. Mangans also line pores or root channels and bridge sand grains.

MODERN SOIL. The portion of a soil section that is under the influence of current pedogenetic conditions. It generally refers to the uppermost soil regardless of age.

MODERN SOLUM. The combination of the A and B horizons in the modern soil.

MORPHOLOGY, SOIL. The physical make-up of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

MOTTLING, SOIL. Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: abundance--few, common, and many; size--fine, medium, and coarse; and contrast--faint, distinct and prominent. The size measurements are these: fine, less than 5 mm in diameter along the greatest dimension; medium, from 5 to 15 mm, and coarse, more than 15 mm.

MRT (MEAN RESIDENCE TIME.) The average age of the carbon atoms within a soil horizon. Under ideal reducing conditions, the humus in a soil will have a C-14 age that is half the true age of the soil. In oxic soils humus is typically destroyed as fast as it is produced, generally yielding MRT ages no older than 300-1000 years, regardless of the true age of the soil.

MUNSELL COLOR NOTATION. Scientific description of color determined by comparing soil to a Munsell Soil Color Chart (Available from Macbeth Division of Kollmorgen Corp., 2441 N. Calvert St., Baltimore, MD 21218). For example, dark yellowish brown is denoted as 10YR3/4m in which the 10YR refers to the hue or proportions of yellow and red, 3 refers to value or lightness (0 is black and 10 is white), 4 refers to chroma (0 is pure black and white and 20 is the pure color), and m refers to the moist condition rather than the dry (d) condition.

OVERBANK DEPOSIT. Fine-grained alluvial sediments deposited from floodwaters outside of the fluvial channel.

OXIC. A soil having a high redox potential. Such soils typically are well drained, seldom being waterlogged or lacking in oxygen. Rubification in such soils tends to increase with age.

PALEO SOIL TONGUE. A soil tongue that formed during a previous soil-forming interval.

PALEOSEISMOLOGY. The study of prehistoric earthquakes through the examination of soils, sediments, and rocks.

PALEOSOL. A soil that formed on a landscape in the past with distinctive morphological features resulting from a soil-forming environment that no longer exists at the site. The former pedogenic process was either altered because of external environmental change or interrupted by burial.

PALINSPASTIC RECONSTRUCTION. Diagrammatic reconstruction used to obtain a picture of what geologic and/or soil units looked like before their tectonic deformation.

PARENT MATERIAL. The great variety of unconsolidated organic and mineral material in which soil forms. Consolidated bedrock is not yet parent material by this concept.

PED. An individual natural soil aggregate, such as a granule, a prism, or a block.

PEDOCHRONOLOGY. The study of pedogenesis with regard to the determination of when soil formation began, how long it occurred, and when it stopped. Also known as soil dating. Two ages and the calculated duration are important:

t_o = age when soil formation or aggradation began, ka

t_b = age when the soil or stratum was buried, ka

t_d = duration of soil development or aggradation, ky

Pedochronological estimates are based on available information. All ages should be considered subject to ±50% variation unless otherwise indicated.

PEDOCHRONOPALEOSEISMOLOGY. The study of prehistoric earthquakes by using pedochronology.

PEDOLOGY. The study of the process through which rocks, sediments, and their constituent minerals are transformed into soils and their constituent minerals at or near the surface of the earth.

PEDOGENESIS. The process through which rocks, sediments, and their constituent minerals are transformed into soils and their constituent minerals at or near the surface of the earth.

PERCOLATION. The downward movement of water through the soil.

pH VALUE. The negative log of the hydrogen ion concentration. Measurements in soils are usually performed on 1:1 suspensions containing one part by weight of soil and one part by weight of distilled water. A soil with a pH of 7.0 is precisely neutral in reaction because it is neither acid nor alkaline. An acid or "sour" soil is one that gives an acid reaction; an alkaline soil is one that gives an alkaline reaction. In words, the degrees of acidity or alkalinity are expressed as:

Extremely acid------- <4.5

Very strongly acid--- 4.5 to 5.0

Strongly acid-------- 5.1 to 5.5

Medium acid---------- 5.6 to 6.0

Slightly acid-------- 6.1 to 6.5

Neutral-------------- 6.6 to 7.3

Mildly alkaline------ 7.4 to 7.8

Moderately alkaline-- 7.9 to 8.4

Strongly alkaline---- 8.5 to 9.0

Very strongly alkaline >9.0

Used if significant:

Very slightly acid--- 6.6 to 6.9

Very mildly alkaline- 7.1 to 7.3

PHREATIC SURFACE. (See Water Table.)

PLANATION. The process of erosion whereby a portion of the surface of the Earth is reduced to a fundamentally even, flat, or level surface by a meandering stream, waves, currents, glaciers, or wind.

PLEISTOCENE. An epoch of geologic time extending from 10 ka to 1.8 Ma; it includes the last Ice Age.

PROFILE, SOIL. A vertical section of the soil through all its horizons and extending into the parent material.

QUATERNARY. A period of geologic time that includes the past 1.8 Ma. It consists of two epochs--the Pleistocene and Holocene.

PROGRADATION. The building outward toward the sea of a shoreline or coastline by nearshore deposition.

RELICT SOIL. A surface soil that was partly formed under climatic conditions significantly different from the present.

RUBIFICATION. The reddening of soils through the release and precipitation of iron as an oxide during weathering. Munsell hues and chromas of well-drained soils generally increase with soil age.

SALINE SOIL. A soil that contains soluble salts in amounts that impair the growth of crop plants but that does not contain excess exchangeable sodium.

SAND. Individual rock or mineral fragments in a soil that range in diameter from 0.05 to 2.0 mm. Most sand grains consist of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

SECONDARY FAULT. A minor fault that bifurcates from or is associated with a primary fault. Movement on a secondary fault never occurs independently of movement on the primary, seismogenic fault.

SHORELINE ANGLE. The line formed by the intersection of the wave-cut platform and the sea cliff. It approximates the position of sea level at the time the platform was formed.

SILT. Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 mm) to the lower limit of very find sand (0.05 mm.) Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

SLICKENSIDES. Polished and grooved surfaces produced by one mass sliding past another. In soils, slickensides may form along a fault plane; at the bases of slip surfaces on steep slopes; on faces of blocks, prisms, and columns undergoing shrink-swell. In tectonic slickensides the striations are strictly parallel.

SLIP RATE. The rate at which the geologic materials on the two sides of a fault move past each other over geologic time. The slip rate is expressed in mm/yr, and the applicable duration is stated. Faults having slip rates less than 0.01 mm/yr are generally considered inactive, while faults with Holocene slip rates greater than 0.1 mm/yr generally display tectonic geomorphology.

SMECTITE. A fine, platy, aluminosilicate clay mineral that expands and contracts with the absorption and loss of water. It has a high cation-exchange capacity and is plastic and sticky when moist.

SOIL. A natural, three-dimensional body at the earth's surface that is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

SOIL SEISMOLOGIST. Soil scientist who studies the effects of earthquakes on soils.

SOIL SLICKS. Curvilinear striations that form in swelling clayey soils, where there is marked change in moisture content. Clayey slopes buttressed by rigid materials may allow minor amounts of gravitationally driven plastic flow, forming soil slicks sometimes mistaken for evidence of tectonism. Soil slicks disappear with depth and the striations are seldom strictly parallel as they are when movement is major. (See also SLICKENSIDES.)

SOIL TECTONICS. The study of the interactions between soil formation and tectonism.

SOIL TONGUE. That portion of a soil horizon extending into a lower horizon.

SOLUM. Combined A and B horizons. Also called the true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

STONELINE. A thin, buried, planar layer of stones, cobbles, or bedrock fragments. Stonelines of geological origin may have been deposited upon a former land surface. The fragments are more often pebbles or cobbles than stones. A stoneline generally overlies material that was subject to weathering, soil formation, and erosion before deposition of the overlying material. Many stonelines seem to be buried erosion pavements, originally formed by running water on the land surface and concurrently covered by surficial sediment.

STRATH TERRACE. A gently sloping terrace surface bearing little evidence of aggradation.

STRUCTURE, SOIL. The arrangement of primary soil particles into compound particles or aggregates that are separated from adjoining aggregates. The principal forms of soil structure are--platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular), and granular. Structureless soils are either single grained (each grain by itself, as in dune sand) or massive (the particles adhering without any regular cleavage, as in many hardpans).

SUBSIDIARY FAULT. A branch fault that extends a substantial distance from the main fault zone.

TECTOTURBATION. Soil disturbance resulting from tectonic movement.

TEXTURE, SOIL. Particle size classification of a soil, generally given in terms of the USDA system which uses the term "loam" for a soil having equal properties of sand, silt, and clay. The basic textural classes, in order of their increasing proportions of fine particles are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sand clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

TOPOSEQUENCE. A sequence of kinds of soil in relation to position on a slope. (See also CATENA.)

TRANSLOCATION. The physical movement of soil particles, particularly fine clay, from one soil horizon to another under the influence of gravity.

UNIFIED SOIL CLASSIFICATION SYSTEM. The particle size classification system used by the U.S. Army Corps of Engineers and the Bureau of Reclamation. Like the ASTM and AASHO systems, the sand/silt boundary is at 80 um instead of 50 um used by the USDA. Unlike all other systems, the gravel/sand boundary is at 4 mm instead of 2 mm and the silt/clay boundary is determined by using Atterberg limits.

VARVE. Lamellae reflecting deposition under seasonal changes in redox conditions. The term “varve,” once used exclusively for glacial lakes, is now used for other fluctuating fresh-water environments as well.

VERTISOL. A soil with at least 30% clay, usually smectite, that fosters pronounced changes in volume with change in moisture. Cracks greater than 1 cm wide appear at a depth of 50 cm during the dry season each year. One of the ten USDA soil orders.

WATER TABLE. The upper limit of the soil or underlying rock material that is wholly saturated with water. Also called the phreatic surface.

WAVE-CUT PLATFORM. The relatively smooth, slightly seaward-dipping surface formed along the coast by the action of waves generally accompanied by abrasive materials.

WEATHERING. All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

WETTING FRONT. The greatest depth affected by moisture due to precipitation.

yr B.P. Uncorrected radiocarbon age expressed in years before present, calculated from 1950. Calendar-corrected ages are expressed in ka, or, if warranted, as A.D. or B.C.

LATE PLEISTOCENE SOIL DEVELOPMENT ON ISOLATED TERRACES AT BEVERLY HILLS, CALIFORNIA

Leighton Consulting, Inc., Irvine, CA, Project No. 603314-005 and Kenney GeoScience, Carlsbad, CA, Project No. JN 723-23

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LATE PLEISTOCENE SOIL DEVELOPMENT ON ISOLATED TERRACES AT BEVERLY HILLS, CALIFORNIA

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INTRODUCTION

An assessment of seismic and landslide risk due to ground movement can be aided greatly by the techniques of pedochronology (Borchardt, 2010, 1998), soil dating. This is because the youngest geological unit overlying fault traces and landslide features is generally a soil horizon. The age and relative activity of ground movement often can be estimated by evaluating the age and relative disturbance of overlying soil units.

Soil horizons exhibit a wide range of physical, chemical, and mineralogical properties that evolve at varying rates. Soil scientists use various terms to describe these properties. A black, highly organic "A" horizon, for example, may form within a few centuries, while a dark brown, clayey "Bt" horizon may take as much as 40,000 years to form. Certain soil properties are invariably absent in young soils. For instance, soils developed in granitic alluvium of the San Joaquin Valley do not have Munsell hues redder than 10YR until they are at least 100,000 years old (Birkeland, 1999; Harden, 1982). Still other properties, such as the movement and deposition of clay-size particles and the precipitation of calcium carbonate at extraordinary depths, indicate soil formation during a climate much wetter than at present. In the absence of a radiometric age date for the material from which a particular soil formed, an estimate of its age must take into account all the known properties of the soil and the landscape and climate in which it evolved.

METHOD

The first step in studying a soil is the compilation of the data necessary for describing it (Birkeland, 1999; Borchardt, 2004). At minimum, this requires a Munsell color chart, hand lens, acid bottle, meter for 1:1 soil:water pH and conductivity measurements. The second step may involve the collection of samples of each horizon for laboratory analysis of particle size. This is done to check the textural classifications made in the field and to evaluate the genetic relationships between horizons and between different soils in the landscape. When warranted, the clay mineralogy and chemistry of the soil also is analyzed to provide additional information on the changes undergone by the initial material from which the soil weathered. The last step is the comparison of this accumulated soil data with that for soils having developed under similar conditions. Such information is scattered in soil survey reports (e.g., Welch, 1981), soil science journals, and consulting reports. In a particular locality, there is seldom enough comparative data available for this purpose. That is why, at the very least, the study of one soil profile always makes the evaluation of the next that much easier.

RESULTS OF THIS EVALUATION

Due to extensive urbanization in the area, there is a paucity of information concerning the age of the oldest alluvial surface upon which much of the city of Beverly Hills is built. Renewed interest in the geology of the area has been spawned by investigations of the Santa Monica and Newport-Inglewood fault systems for an extension of Metro (Parsons, 2011) and remodelling of Beverly Hills High School (Borchardt, 2012). The map published by Meigs and others (1999) shows the area from the Cheviot Hills to north of the Santa Monica fault to be "upper Pleistocene." We tested this assertion by studying two relatively undisturbed soil profiles: one in a seismic hazard trench at Beverly Hills High School (Soil Profile No. 1) and one in a hand-dug soil pit along Wilshire Boulevard at the Los Angeles County Club (Soil Profile No. 8). The comparison between these two soils with other soils of the region yields a soil age estimate that confirms Meigs and others (1999).

Soil Profile No. 8

Soil Profile No. 8 was studied to assess the age of the alluvial surface near the crest of an anticline on Wilshire Boulevard north of Beverly Hills High School. This soil had a 39-cm thick brown silt loam A horizon with fine to medium strong granular to subangular blocky structure and a few thin patchy clay films on sand grains. The underlying Bt horizon was a 10-cm thick dark brown gravelly clay loam with common thin patchy clay films on sand grains and lining pores. The underlying 2Bt horizon was a 51-cm thick brown gravelly clay with very few fine faint red (2.5YR5/6md) mottles due to weathered granitic clasts from a prior landscape. Although all the colors were brown, imped (inside the ped) colors were 7.5YR4/2m/10YR5/3d and exped colors were 7.5YR4/4md. There were common medium prominent dark gray (7.5YR4/0m) angular to subrounded slate clasts. Soil structure was medium strong subangular to angular blocky and there were common thin to medium thick clay films on sand grains, peds, and pores. The underlying 3Bt1 horizon was a 30-cm thick brown (10YR4/3m, 7/4d exped; 7.5YR4/2m, 6/4d imped) clay with medium moderate prismatic to angular blocky structure with mottles and clay films similar to the horizon above. The underlying 3Bt2 horizon was a 26-cm thick brown (7.5YR4/4m, 7/4d) gravelly clay with medium moderate subangular blocky structure with mottles and clay films similar to the above horizon.

The remaining horizons had weak soil structure, with the underlying 4BCt horizon being a 37-cm thick brown gravelly clayey sand with fine weak subangular blocky structure with mottles and clay films similar to the above horizon. The underlying 5BCt horizon was a 9-cm thick brown gravelly sand with fine weak subangular blocky structure with similar clay films on sand grains and peds, pores, and interstices. The underlying 6BCt1 horizon was an 18-cm thick brown clayey sand with common thin to medium thick clay films on sand grains, peds, pores and interstices. The base of the horizon had common medium thick clay films and unlike all the horizons above, it was extremely hard when dry. Refusal to hand auger occurred at 210-cm.

DISCUSSION

Comparative Pedology

This profile (Table 1; Figure 1 and Figure 2) was similar to Soil Profile No. 1 (Figure 3) studied in Trench FT-1 at Beverly Hills High School (Borchardt, 2012). Both have silt loam A horizons and brown colors with chromas varying from 7.5YR to 10YR. Both have Bt horizons that are over a meter thick overlying sandy and gravelly BCt and CBt horizons that have common thin to medium thick clay films. The Bt in Soil Profile No. 8 is only 107 cm, while the Bt in Soil Profile No. 1 is 175 cm. This is probably because the upper alluvial unit in Soil Profile No. 8 was initially very gravelly, while the upper alluvial unit in Soil Profile No. 1 was initially very silty (compare Figure 2 and Figure 3). Though at different depths, the Bt/BCt boundaries are similar (compare Figure 3 and Figure 4). The pH and conductivities of both soils are similar (Figures 5 through 7). Thus, whatever their ages, both soils appear to be quite similar after the variations in initial materials are taken into account. There is no reason to believe they have formed on significantly different fan surfaces.

Because there are no well-dated soils in the Beverly Hills area, we necessarily need to make comparisons with soils at a distance. Some of the best soil age estimates are from terraces along the California coast. Here, we must be careful to consider the properties of the initial material. Most marine terraces consist of a wave-cut platform overlain by marine sand, which is subsequently overlain by continental alluvium shed from the surrounding cliffs. When drainages do not allow augmentation by clay-containing alluvium, Bt horizons are likely to be thin to nonexistent, yielding soil development indices that are inordinately low. For example, marine sands on the 122-ka Sangamon terrace at Bodega Bay escaped alluvial deposition, with Bt horizons being as thin 20-cm even though 7.5YR colors reached depths of 3.8 m or more (Borchardt, 1993). Closer to our site, a possible Sangamon-age terrace 45 km north of San Diego had a 10YR loamy sand with only a few clay lamellae having 7.5YR and 5YR colors reaching a depth of 4.2 m (Torrent and others, 1980b). When there is alluvium, and it contains mostly silt, colors redder than 10YR may not even appear in early and late Wisconsin soils developed after the Sangamon highstand (Borchardt, 1988). Soils on coastal terraces with ages greater than 122 ka typically have much redder colors than those seen in Soil Profile Nos. 1 and 8. For instance, a soil on a terrace near Torrey Pines, which might be as old as early Pleistocene, had red 2.5YR colors reaching depths over 5.8 m (Torrent and others, 1980a).

Closer to the site, the Ventura River terraces start having 7.5YR colors after 38 ka, but do not have 5YR colors until after 80 ka (Rockwell and others, 1985, p. 317). As in our profiles, horizons with translocated clay were up to several meters thick. Nonetheless, ours were not 5.7-

20 m thick as in the 160-200 ka soils at Ventura. We must conclude, instead, that our profiles are similar to the 80-ka soils at Ventura.

As mentioned, Meigs and others (1999) considered the abandoned surfaces in the area to be “upper Pleistocene,” that is, late Pleistocene, the time since 122 ka (Chen and others, 1991). This fits our estimated soil age of 80 ka, which must be considered a minimum. The surface likely was abandoned after the rapid drop in base level that occurred with the advance of the Wisconsin continental glaciers and associated decrease in sea level after MIS (marine isotope stage) 5a. Being of similar age, both of our profiles easily could be parts of the same alluvial fan. The 58’ (344’-286’) difference in elevation between them yields a 1.8% slope over a 3,265’ distance. As expected, this is a bit lower than the 2.2% slope that extends in the opposite direction for xxx’ toward the northern end of the golf course, which would have comprised the distal portion of the fan on which the two soils formed.

CONCLUSION

Soil Profile Nos. 1 and 8 probably formed on the same alluvial fan during the last 80,000 years.

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Table 1. Description of Soil Profile No. 8 from an excavation on Wilshire Boulevard north of Beverly Hills High School, Beverly Hills, California. Abbreviations and definitions are given in Soil Survey Staff (1992; 1993; 1999).

Description of soil profile developed in Pleistocene alluvium by Glenn Borchardt, who measured and sampled the soil on February 23, 2012 at latitude N34^o 04.052' and longitude W118^o 25.260' in the south wall of a hand-dug pit at an elevation of 344'. Mediterranean climate with mean annual precipitation of 13.15"/yr (334 mm/yr) at Santa Monica from 1947 to 1979. Pepper trees and other ornamentals. Slope 0.5%. Aspect south. Excellent drainage. Water deep. The parent material is clay to gravelly sand alluvium. Soil pH is slightly acid in the topsoil and mildly alkaline in the subsoil.

Horizon	Depth, cm	Description

A 0-39 Brown (7.5YR4/2m, 10YR6/2d) silt loam; fine to medium strong granular to subangular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and very hard when dry; common fine to medium and few coarse roots; common fine to medium continuous random tubular pores; few thin patchy clay films on sand grains; clear smooth boundary; pH 6.4; conductivity 550 uS; Sample No. 12B201.

Bt 39-49 Dark brown (7.5YR3/2m, 10YR5/4d) gravelly clay loam with very few fine faint red (2.5YR5/6md) mottles due to weathered granitic clasts from a prior landscape; fine to medium strong subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; common fine to medium roots; common fine continuous random tubular pores; common thin patchy clay films on sand grains and lining pores; gradual smooth boundary; pH 7.4; conductivity 770 uS; Sample No. 12B202.

2Bt 49-90 Brown (7.5YR4/2m, 10YR5/3d [imped]; 7.5YR4/4md [exped]) gravelly clay with very few fine faint red (2.5YR5/6md) mottles due to weathered granitic clasts from a prior landscape and few fine to medium distinct very pale brown (10YR8/4md) mottles due to coarse granitic sand grains and common medium prominent dark gray (7.5YR4/0m) angular to subrounded slate clasts; medium strong subangular to angular blocky structure; very sticky and very plastic when wet, very friable when moist, and very hard when dry; few fine to medium roots; few fine continuous random tubular pores; common thin to medium thick clay films on sand grains, peds, and pores; clear wavy boundary; pH 7.4; conductivity 1240 uS; Sample No. 12B203.

3Bt1 90-120 Brown (10YR4/3m, 7/4d exped; 7.5YR4/2m, 6/4d imped) clay with very few fine faint red (2.5YR5/6md) mottles due to weathered granitic clasts from a prior landscape and few fine to medium distinct very pale brown (10YR8/4md) mottles due to coarse granitic sand grains and common medium prominent dark gray (7.5YR4/0m) angular slate clasts; medium moderate prismatic to angular blocky structure; very sticky and very plastic when wet, firm when moist, and very hard when dry; few fine to medium roots; few fine continuous random tubular pores; common thin to medium thick clay films on sand grains and peds; gradual smooth boundary; pH 7.4; conductivity 1650 uS; Sample No. 12B204.

3Bt2 120-146 Brown (7.5YR4/4m, 7/4d) gravelly clay with very few fine faint red (2.5YR5/6md) mottles due to weathered granitic clasts from a prior landscape and few fine to medium distinct very pale brown (10YR8/4md) mottles due to coarse granitic sand grains and common medium prominent dark gray (7.5YR4/0m) subrounded slate clasts; medium moderate subangular blocky structure; very sticky and very plastic when wet, friable when moist, and very hard when dry; few fine continuous random tubular pores; common thin to medium thick clay films on sand grains and peds; abrupt smooth boundary; pH 7.6; conductivity 1290 uS; Sample No. 12B205.

4BCt1 146-183 Brown (7.5YR4/4m, 10YR7/4d) gravelly clayey sand with very few fine faint red (2.5YR5/6md) mottles due to weathered granitic clasts from a prior landscape and few fine to medium distinct very pale brown (10YR8/4md) mottles due to coarse granitic sand grains and common medium prominent dark gray (7.5YR4/0m) subrounded to angular slate clasts; fine weak subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few fine continuous random tubular and interstitial pores; common thin to medium thick clay films on sand grains, peds, and pores; pH 7.5; conductivity 1180 uS; Sample No. 12B206.

5BCt 183-192 Brown (7.5YR5/4m, 10YR7/4d) gravelly sand with common medium prominent dark gray (7.5YR4/0m) subrounded to angular slate clasts; fine weak subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few fine continuous random tubular and interstitial pores; common thin to medium thick clay films on sand grains, peds, and pores and interstices; pH 7.6; conductivity 1170 uS; Sample No. 12B207.

6BCt1 192-201 Brown (7.5YR5/4m, 10YR7/4d) clayey sand with common medium distinct pinkish gray (7.5YR6/2m) mottles due to peds and dark gray mottles due to subrounded slate clasts; massive to fine weak subangular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few fine continuous random tubular and interstitial pores; common thin to medium thick clay films on sand grains, peds, pores, and interstices; pH 7.5; conductivity 1110 uS; Sample No. 12B208.

6BCt2 201-210 Brown (7.5YR5/4m, 10YR7/4d) clayey sand with few medium to coarse distinct red (2.5YR4/6m) mottles due to weathered granitic clasts from a prior landscape; medium moderate subangular blocky structure; sticky and plastic when wet, very friable when moist, and extremely hard when dry; few fine continuous random tubular and interstitial pores; common medium thick clay films on sand grains, peds, pores, and interstices; pH 7.3; conductivity 1130 uS; Sample No. 12B209.

*ESTIMATED AGE:	t_o	=	80	ka
	t_b	=	0	ka
	t_d	=	80	ky

[*]Pedochronological estimates based on available information. All ages should be considered subject to $\pm$50% variation unless otherwise indicated (Borchardt, 2010). Bold dates are absolute.
t_o = date when soil formation or aggradation began, ka
t_b = date when soil or strata was buried, ka
t_d = duration of soil development or aggradation, ky

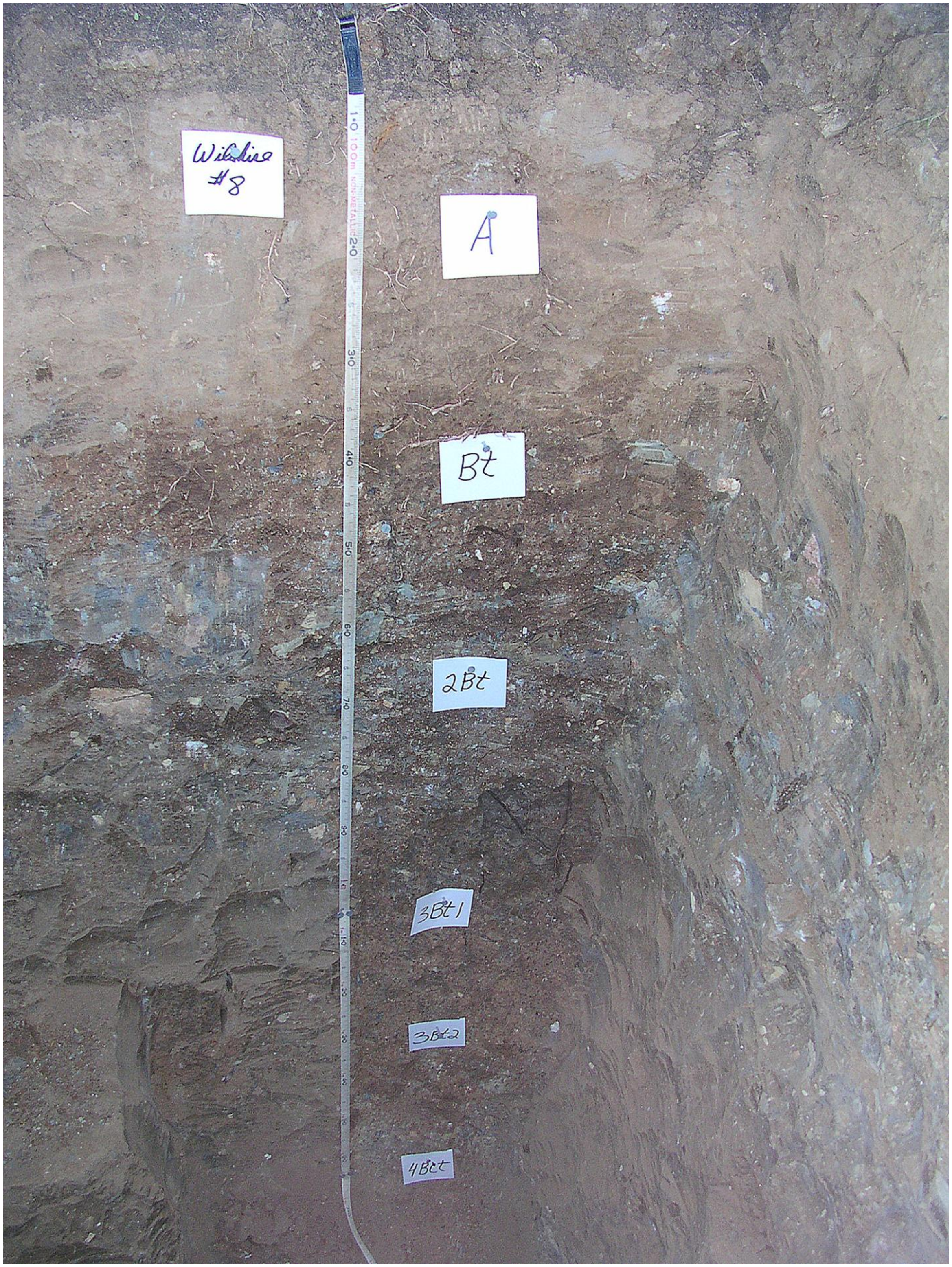

Figure 1. Soil Profile No. 8 in a hand-dug pit along Wilshire Boulevard.

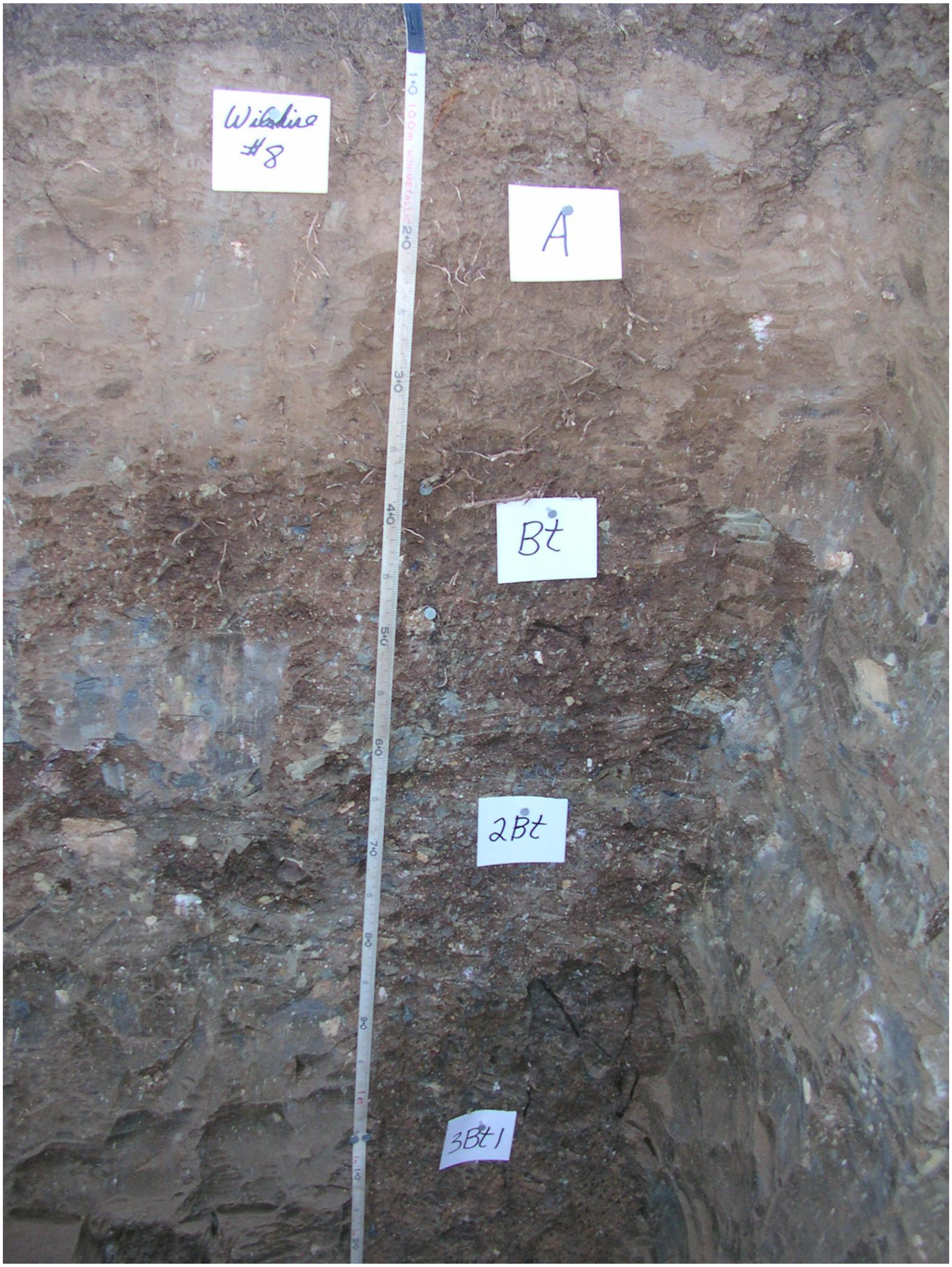

Figure 2. Close-up of the upper 120 cm of Soil Profile No. 8.

Figure 3. Bt/BCt contact at 210 cm in Soil Profile No. 1. Subtracting the fill, the actual depth would be 196 cm, with the Bt horizon being 175 cm thick.

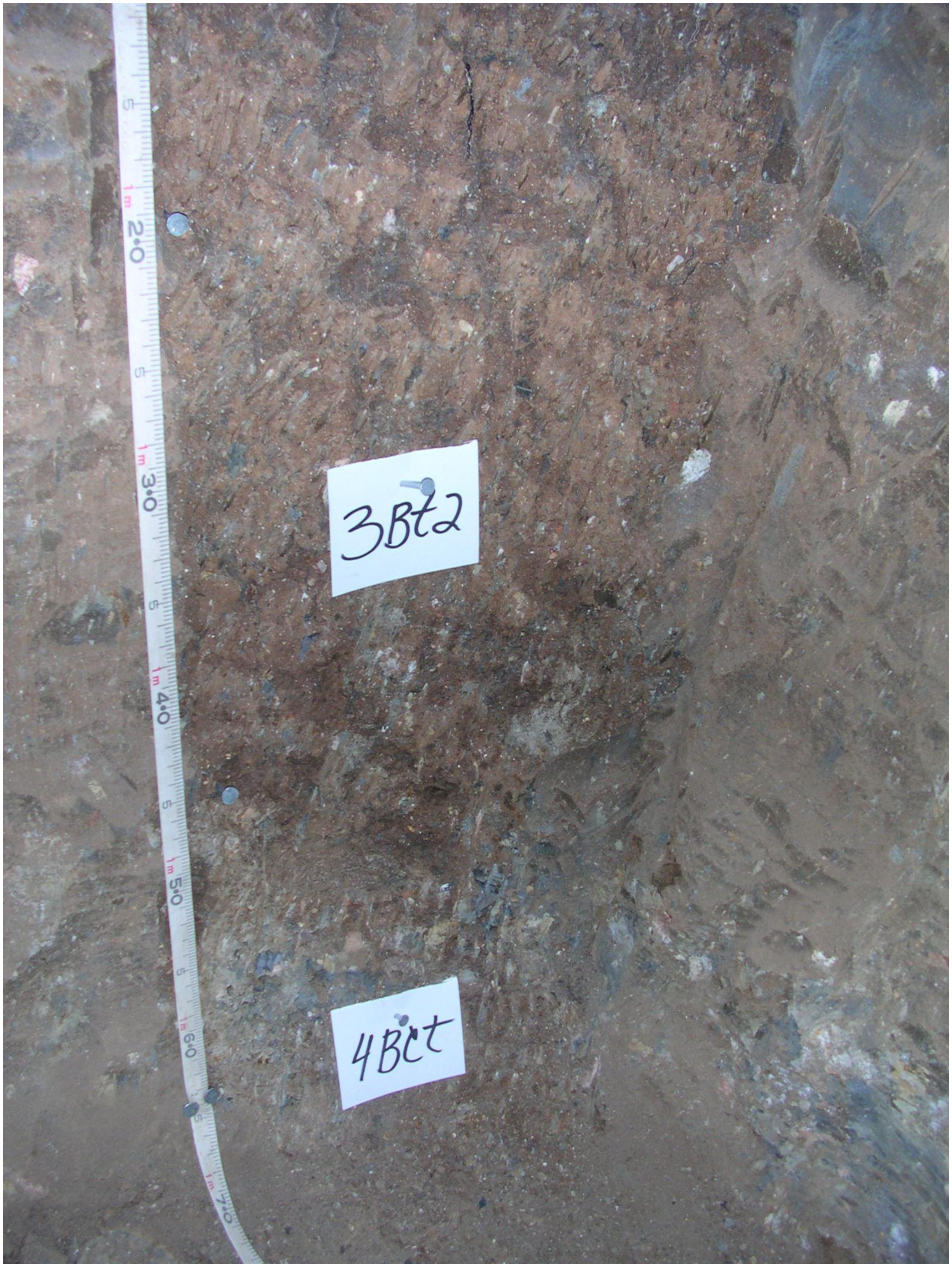

Figure 4. Close-up of the Bt/BCt boundary at the base of the solum in Soil Profile No. 8.

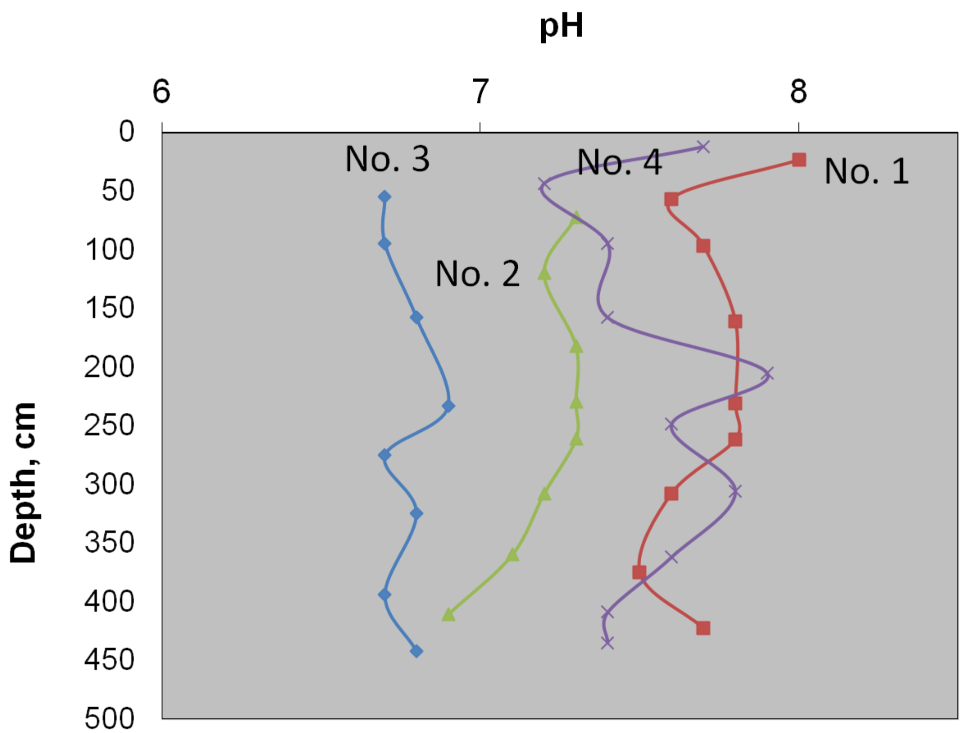

Figure 5. Soil pH of the four profiles studied at Beverly Hills High School. Note that Soil Profile Nos. 2 and 3 are more acidic than either No. 1 or No. 4.

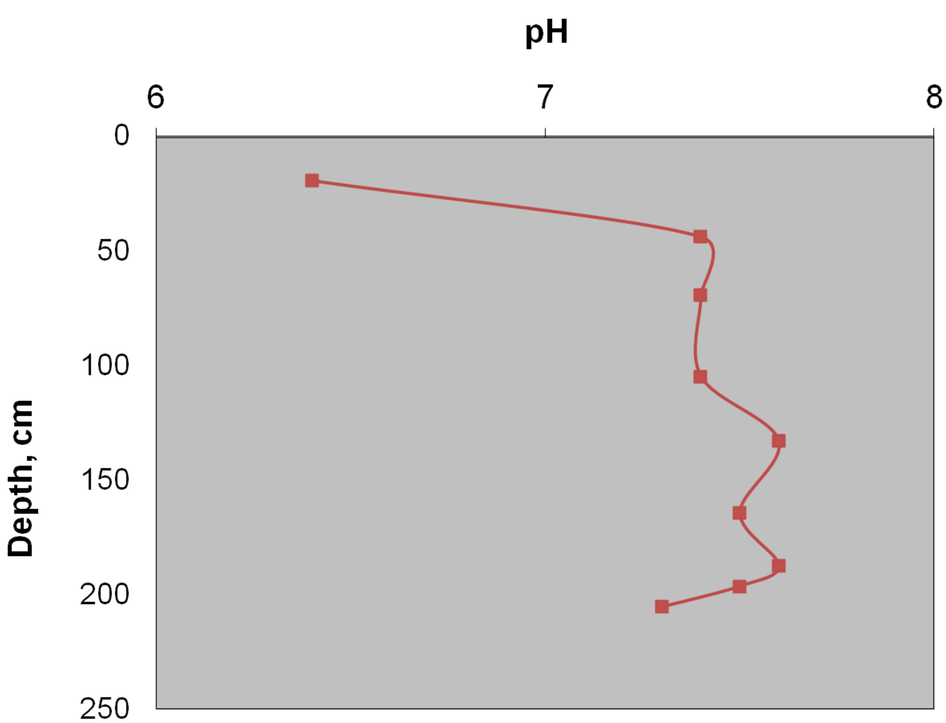

Figure 6. Soil pH for Soil Profile No. 8 at Wilshire Boulevard.

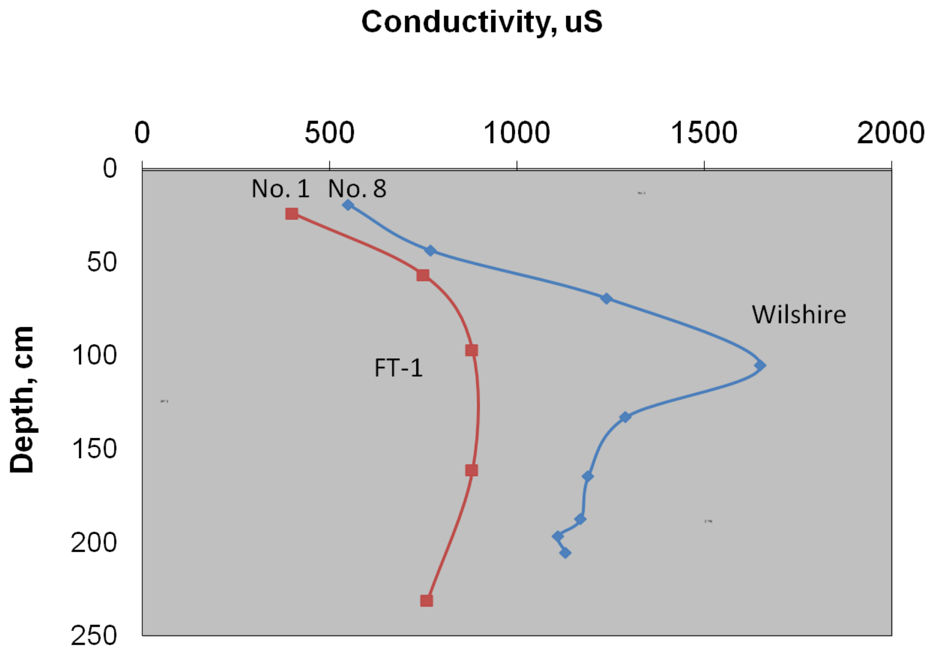

Figure 7. Conductivity in Soil Profile Nos. 1 and 8 from Trench FT-1 at BHHS and the soil pit at Wilshire Boulevard.

SOILS GLOSSARY

AGE. Elapsed time in calendar years. Because the cosmic production of C-14 has varied during the Quaternary, radiocarbon years (expressed as ky B.P.) must be corrected by using tree-ring and other data. Abbreviations used for corrected ages are: ka (kilo anno or years in thousands) or Ma (millions of years). Abbreviations used for intervals are: yr (years), ky (thousands of years). radiocarbon ages = yr B.P. Calibrated ages are calculated from process assumptions, relative ages fit in a sequence, and correlated ages refer to a matching unit. (See also yr B.P., HOLOCENE, PLEISTOCENE, QUATERNARY, PEDOCHRONOLOGY).

AGGRADATION. A modification of the earth's surface in the direction of uniformity of grade by deposition.

ALKALI (SODIC) SOIL. A soil having so high a degree of alkalinity (pH 8.5 or higher), or so high a percentage of exchangeable sodium (15 % or more of the total exchangeable bases), or both, that plant growth is restricted.

ALKALINE SOIL. Any soil that has a pH greater than 7.3. (See Reaction, Soil.)

ANGULAR ORPHANS. Angular fragments separated from weathered, well-rounded cobbles in colluvium derived from conglomerate.

ARGILLAN. (See Clay Film.)

ARGILLIC horizon. A horizon containing clay either translocated from above or formed in place through pedogenesis.

ALLUVIATION. The process of building up of sediments by a stream at places where stream velocity is decreased. The coarsest particles settle first and the finest particles settle last.

ANOXIC. (See also GLEYED SOIL). A soil having a low redox potential.

AQUICLUDE. A saturated body of sediment or rock that is incapable of transmitting significant quantities of water under ordinary hydraulic gradients.

AQUITARD. A body of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs but may serve as a storage unit for groundwater.

ATTERBERG LIMITS. The moisture content at which a soil passes from a semi-solid to a plastic state (plastic limit, PL) and from a plastic to a liquid state (liquid limit, LL). The plasticity index (PI) is the numerical difference between the LL and the PL.

BEDROCK. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

BISEQUUM. Two soils in vertical sequence, each soil containing an eluvial horizon and its underlying B horizon.

BOUDIN, BOUDINAGE. From a French word for sausage, describes the way that layers of rock break up under extension. Imagine the hand, fingers together, flat on the table, encased in soft clay and being squeezed from above, as being like a layer of rock. As the spreading clay moves the fingers (sausages) apart, the most mobile rock fractions are drawn or squeezed into the developing gaps.

BURIED SOIL. A developed soil that was once exposed but is now overlain by a more recently formed soil.

CALCAREOUS SOIL. A soil containing enough calcium carbonate (commonly with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid. A soil having measurable amounts of calcium carbonate or magnesium carbonate.

CARBONATE MORPHOLOGY STAGES. Descriptive classes of calcite precipitation indicating increasing pedogenesis over time:

Stage		% $CaCO_3$
I	Bk horizon with few filaments and coatings	<10
I+	Bk with common filaments and continuous clast coatings	<10
II	Bk with continuous clast coatings, white masses, few nodules	>10
II+	Bk as above, but matrix is completely whitened, common nodules	>15
III	K horizon that is 90% white, many nodules	>20
III+	K that is completely plugged	>40
IV	K as above, but upper part cemented and has weak platy structure	>50
V	K same as above, but laminar layer is strong with incipient brecciation	>50
VI	K brecciation and recementation, as well as pisoliths, are common	>50

CATENA. A sequence of soils of about the same age, derived from similar parent material and forming under similar climatic conditions, but having different characteristics due to variation in relief and drainage. (See also TOPOSEQUENCE.)

CEC. Cation exchange capacity. The amount of negative charge balanced by positively charged ions (cations) that are exchangeable by other cations in solution (meq/100 g soil = cmol(+)/kg soil).

CLAY. As a soil separate, the mineral soil particles are less than 0.002 mm in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

CLAY FILM. A coating of oriented clay on the surface of a sand grain, pebble, soil aggregate, or ped. Clay films also line pores or root channels and bridge sand grains. Frequency classification is based on the percent of the ped faces and/or pores that contain films: very few--<5%; few--5-25%; common--25-50%; many--50-90%; and continuous--90-100%. Thickness classification is based on visibility of sand grains: thin--very fine sand grains standout; moderately thick--very fine sand grains impart microrelief to film; thick--fine sand grains enveloped by clay and films visible without magnification. Synonyms: clay skin, clay coat, argillan, illuviation cutan.

CLAY LAMELLAE. Thin, generally wavy bands that appear as multiple micro-Bt horizons at the base of the solum in sandy Holocene deposits. The lamellae generally are 1-3 cm in thickness and 5 to 30 cm apart. There may be two to six or more clay lamellae comprising the Bt horizon of such a soil.

COBBLE. Rounded or partially rounded fragments of rock ranging from 7.5 to 25 cm in diameter.

COLLUVIUM. Any loose mass of soil or rock fragments that moves downslope largely by the force of gravity. Usually it is thicker at the base of the slope.

COLLUVIUM-FILLED SWALE. The prefailure topography of the source area of a debris flow.

COMPARATIVE PEDOLOGY. The comparison of soils, particularly through examination of features known to evolve through time.

CONCRETIONS. Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrated compounds or cemented soil grains. The composition of most concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are common compounds in concretions.

CONDUCTIVITY. The ability of a soil solution to conduct electricity, generally expressed as the reciprocal of the electrical resistivity. Electrical conductance is the reciprocal of the resistance (1/R = 1/ohm = ohm^{-1} = mho [reverse of ohm] = siemens = S), while electrical conductivity is the reciprocal of the electrical resistivity (EC = 1/r = 1/ohm-cm = mho/cm = S/cm or mmho/cm = dS/m). EC, expressed as uS/cm, is equivalent to the ppm of salt in solution when multiplied by 0.640. Pure rain water has an EC of 0, standard 0.01 N KCl is 1411.8 uS at 25C, and the growth of salt-sensitive crops is restricted in soils having saturation extracts with an EC greater than 2,000 uS/cm. Measurements in soils are usually performed on 1:1 suspensions containing one part by weight of soil and one part by weight of distilled water.

CONSISTENCE, SOIL. The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are --

Loose.--Noncoherent when dry or moist; does not hold together in a mass.

Friable.--When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm.--When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.--When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

Sticky.--When wet, adheres to other material, and tends to stretch somewhat and pull apart, rather than to pull free from other material.

Hard.--When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.--When dry, breaks into powder or individual grains under very slight pressure.

Cemented.--Hard and brittle; little affected by moistening.

CTPOT. Easily remembered acronym for climate, topography, parent material, organisms, and time; the five factors of soil formation.

CUMULIC. A soil horizon that has undergone aggradation coincident with its active development.

CUTAN. (See Clay Film.)

DEBRIS FLOW. Incoherent or broken masses of rock, soil, and other debris that move downslope in a manner similar to a viscous fluid.

DEBRIS SLOPE. A constant slope with debris on it from the free face above.

DEGRADATION. A modification of the earth's surface by erosion.

DURIPAN. A subsurface soil horizon that is cemented by illuvial silica, generally deposited as opal or microcrystalline silica, to the degree that less than 50 percent of the volume of air-dry fragments will slake in water or HCl.

ELUVIATION. The removal of soluble material and solid particles, mostly clay and humus, from a soil horizon by percolating water.

EOLIAN. Deposits laid down by the wind, landforms eroded by the wind, or structures such as ripple marks made by the wind.

FAULT-LINE SCARP. A scarp that has been produced by differential erosion along an old fault line.

FAULTSLIDE. A landslide that shows physical evidence of its interaction with a fault.

FIRST-ORDER DRAINAGE. The most upstream, field-discernible concavity that conducts water and sediments to lower parts of a watershed.

FLOOD PLAIN. A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

FOSSIL FISSURE. A buried rectilinear chamber associated with extension due to ground movement. The chamber must be oriented along the strike of the shear and must have vertical and horizontal dimensions greater than its width. It must show no evidence of faunal activity and its walls may have silt or clay coatings indicative of frequent temporary saturation with ground water. May be mistaken for an animal burrow. Also known as a paleofissure.

FRIABILITY. Term for the ease with which soil crumbles. A friable soil is one that crumbles easily.

GENESIS, SOIL. The mode of origin of the soil. Refers especially to the processes or soil-forming factors responsible for the formation of the solum (A and B horizons) from the unconsolidated parent material.

GEOMORPHIC. Pertaining to the form of the surface features of the earth. Specifically, geomorphology is the analysis of landforms and their mode of origin.

GLEYED SOIL. A soil having one or more neutral gray horizons as a result of water logging and lack of oxygen. The term "gleyed" also designates gray horizons and horizons having yellow and gray mottles as a result of intermittent water logging.

GRAVEL. Rounded or angular fragments of rock 2 to 75 mm in diameter. Soil textures with >15% gravel have the prefix "gravelly" and those with >90% gravel have the suffix "gravel."

HIGHSTAND. The highest elevation reached by the ocean during an interglacial period.

HOLOCENE. The most recent epoch of geologic time, extending from 10 ka to the present.

HORIZON, SOIL. A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major soil horizons:

> O horizon.--The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.
>
> A horizon.--The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).
>
> E horizon -- This eluvial horizon is light in color, lying beneath the A horizon and above the B horizon. It is made up mostly of sand and silt, having lost most of its clay and iron oxides through reduction, chelation, and translocation.
>
> B horizon.--The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these.
>
> C horizon.--The relatively unweathered material immediately beneath the solum. Included are sediment, saprolite, organic matter, and bedrock excavatable with a spade. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a number precedes the letter C.
>
> R horizon.--Consolidated rock not excavatable with a spade. It may contain a few cracks filled with roots or clay or oxides. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

Major horizons may be further distinguished by applying prefix Arabic numbers to designate differences in parent materials as they are encountered (e.g., 2B, 2BC, 3C) or by applying suffix numerals to designate minor changes (e.g., B1, B2).

The following is from Soil Survey Staff (2006):

"Suffix Symbols

Lowercase letters are used as suffixes to designate specific kinds of master horizons and layers. The term "accumulation" is used in many of the definitions of such horizons to indicate that these horizons must contain more of the material in question than is presumed to have been present in the parent material. The suffix symbols and their meanings are as follows:

a Highly decomposed organic material

This symbol is used with O to indicate the most highly decomposed organic materials, which have a fiber content of less than 17 percent (by volume) after rubbing.

b Buried genetic horizon

This symbol is used in mineral soils to indicate identifiable buried horizons with major genetic features that were developed before burial. Genetic horizons may or may not have formed in the overlying material, which may be either like or unlike the assumed parent material of the buried soil. This symbol is not used in organic soils, nor is it used to separate an organic layer from a mineral layer.

c *Concretions or nodules*

This symbol indicates a significant accumulation of concretions or nodules. Cementation is required. The cementing agent commonly is iron, aluminum, manganese, or titanium. It cannot be silica, dolomite, calcite, or more soluble salts.

co *Coprogenous earth*

This symbol, used only with L, indicates a limnic layer of coprogenous earth (or sedimentary peat).

d *Physical root restriction*

This symbol indicates noncemented, root-restricting layers in natural or human-made sediments or materials. Examples are dense basal till, plowpans, and other mechanically compacted zones.

di *Diatomaceous earth*

This symbol, used only with L, indicates a limnic layer of diatomaceous earth.

e *Organic material of intermediate decomposition*

This symbol is used with O to indicate organic materials of intermediate decomposition. The fiber content of these materials is 17 to 40 percent (by volume) after rubbing.

f *Frozen soil or water*

This symbol indicates that a horizon or layer contains permanent ice. The symbol is not used for seasonally frozen layers or for dry permafrost.

ff *Dry permafrost*

This symbol indicates a horizon or layer that is continually colder than 0 oC and does not contain enough ice to be cemented by ice. This suffix is not used for horizons or layers that have a temperature warmer than 0 oC at some time of the year.

g *Strong gleying*

This symbol indicates either that iron has been reduced and removed during soil formation or that saturation with stagnant water has preserved it in a reduced state. Most of the affected layers have chroma of 2 or less, and many have redox concentrations. The low chroma can represent either the color of reduced iron or the color of uncoated sand and silt particles from which iron has been removed. The symbol g is not used for materials of low chroma that have no history of wetness, such as some slates or E horizons. If g is used with B, pedogenic change in addition to gleying is implied. If no other pedogenic change besides gleying has taken place, the horizon is designated Cg.

h *Illuvial accumulation of organic matter*

This symbol is used with B to indicate the accumulation of illuvial, amorphous, dispersible complexes of organic matter and sesquioxides if the sesquioxide component is dominated by aluminum but is present only in very small quantities. The organo-sesquioxide material coats sand and silt particles. In some horizons these coatings have coalesced, filled pores, and cemented the horizon. The symbol h is also used in combination with s as “Bhs” if the amount of the sesquioxide component is significant but the color value and chroma, moist, of the horizon are 3 or less.

i *Slightly decomposed organic material*

This symbol is used with O to indicate the least decomposed of the organic materials. The fiber content of these materials is 40 percent or more (by volume) after rubbing.

j *Accumulation of jarosite*

Jarosite is a potassium or iron sulfate mineral that is commonly an alteration product of pyrite that has been exposed to an oxidizing environment. Jarosite has hue of 2.5Y or yellower and normally has chroma of 6 or more, although chromas as low as 3 or 4 have been reported. [Note: No longer used to indicate “juvenile.”]

jj *Evidence of cryoturbation*

Evidence of cryoturbation includes irregular and broken horizon boundaries, sorted rock fragments, and organic soil materials existing as bodies and broken layers within and/or between mineral soil layers. The organic bodies and layers are most commonly at the contact between the active layer and the permafrost.

k *Accumulation of secondary carbonates*

This symbol indicates an accumulation of visible pedogenic calcium carbonate (less than 50 percent, by volume). Carbonate accumulations exist as carbonate filaments, coatings, masses, nodules, disseminated carbonate, or other forms.

kk *Engulfment of horizon by secondary carbonates*

This symbol indicates major accumulations of pedogenic calcium carbonate. The suffix kk is used when the soil fabric is plugged with fine grained pedogenic carbonate (50 percent or more, by volume) that exists as an essentially continuous medium. The suffix corresponds to the stage III plugged horizon or higher of the carbonate morphogenetic stages (Gile et al., 1966).

m *Cementation or induration*

This symbol indicates continuous or nearly continuous cementation. It is used only for horizons that are more than 90 percent cemented, although they may be fractured. The cemented layer is physically root-restrictive. The dominant cementing agent (or the two dominant ones) may be indicated by adding defined letter suffixes, singly or in pairs. The horizon suffix km indicates cementation by carbonates; qm, cementation by silica; sm, cementation by iron; ym, cementation by gypsum; kqm, cementation by lime and silica; and zm, cementation by salts more soluble than gypsum.

ma *Marl*

This symbol, used only with L, indicates a limnic layer of marl.

n *Accumulation of sodium*

This symbol indicates an accumulation of exchangeable sodium.

o *Residual accumulation of sesquioxides*

This symbol indicates a residual accumulation of sesquioxides.

p *Tillage or other disturbance*

This symbol indicates a disturbance of the surface layer by mechanical means, pasturing, or similar uses. A disturbed organic horizon is designated Op. A disturbed mineral horizon is designated Ap even though it is clearly a former E, B, or C horizon.

q *Accumulation of silica*

This symbol indicates an accumulation of secondary silica.

r *Weathered or soft bedrock*

This symbol is used with C to indicate cemented layers (moderately cemented or less cemented). Examples are weathered igneous rock and partly consolidated sandstone, siltstone, or slate. The excavation difficulty is low to high.

s *Illuvial accumulation of sesquioxides and organic matter*

This symbol is used with B to indicate an accumulation of illuvial, amorphous, dispersible complexes of organic matter and sesquioxides if both the organic-matter and sesquioxide components are significant and if either the color value or chroma, moist, of the horizon is 4 or more. The symbol is also used in combination with h as “Bhs” if both the organic-matter and sesquioxide components are significant and if the color value and chroma, moist, are 3 or less.

ss *Presence of slickensides*

This symbol indicates the presence of slickensides. Slickensides result directly from the swelling of clay minerals and shear failure, commonly at angles of 20 to 60 degrees above horizontal. They are indicators that other vertic characteristics, such as wedge-shaped peds and surface cracks, may be present.

t *Accumulation of silicate clay*

This symbol indicates an accumulation of silicate clay that either has formed *in situ* within a horizon or has been moved into the horizon by illuviation, or both. At least some part of the horizon should show evidence of clay accumulation either as coatings on surfaces of peds or in pores, as lamellae, or as bridges between mineral grains.

u *Presence of human-manufactured materials (artifacts)*

This symbol indicates the presence of manufactured artifacts that have been created or modified by humans, usually for a practical purpose in habitation, manufacturing, excavation, or construction activities. Examples of artifacts are processed wood products, liquid petroleum products, coal, combustion by-products, asphalt, fibers and fabrics, bricks, cinder blocks, concrete, plastic, glass, rubber, paper, cardboard, iron and steel, altered metals and minerals, sanitary and medical waste, garbage, and landfill waste.

v *Plinthite*

This symbol indicates the presence of iron-rich, humus-poor, reddish material that is firm or very firm when moist and hardens irreversibly when exposed to the atmosphere and to repeated wetting and drying.

w *Development of color or structure*

This symbol is used with B to indicate the development of color or structure, or both, with little or no apparent illuvial accumulation of material. It should not be used to indicate a transitional horizon.

x *Fragipan character*

This symbol indicates a genetically developed layer that has a combination of firmness and brittleness and commonly a higher bulk density than the adjacent layers. Some part of the layer is physically root-restrictive.

y *Accumulation of gypsum*

This symbol indicates an accumulation of gypsum.

z *Accumulation of salts more soluble than gypsum*

This symbol indicates an accumulation of salts that are more soluble than gypsum."

HUMUS. The well-decomposed, more or less stable part of the organic matter in mineral soils.

ILLUVIATION. The deposition by percolating water of solid particles, mostly clay or humus, within a soil horizon.

INTERFLUVE. The land lying between streams.

ISOCHRONOUS BOUNDARY. A gradational boundary between two sedimentary units indicating that they are approximately the same age. Opposed to a nonisochronous boundary, which by its abruptness indicates that it delineates units having significant age differences.

KROTOVINA. An animal burrow filled with soil.

LEACHING. The removal of soluble material from soil or other material by percolating water.

LOWSTAND. The lowest elevation reached by the ocean during a glacial period.

MANGAN. A thin coating of manganese oxide (cutan) on the surface of a sand grain, pebble, soil aggregate, or ped. Mangans also line pores or root channels and bridge sand grains.

MODERN SOIL. The portion of a soil section that is under the influence of current pedogenetic conditions. It generally refers to the uppermost soil regardless of age.

MODERN SOLUM. The combination of the A and B horizons in the modern soil.

MORPHOLOGY, SOIL. The physical make-up of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

MOTTLING, SOIL. Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: abundance--few, common, and many; size--fine, medium, and coarse; and contrast--faint, distinct and prominent. The size measurements are these: fine, less than 5 mm in diameter along the greatest dimension; medium, from 5 to 15 mm, and coarse, more than 15 mm.

MRT (MEAN RESIDENCE TIME.) The average age of the carbon atoms within a soil horizon. Under ideal reducing conditions, the humus in a soil will have a C-14 age that is half the true age of the soil. In oxic soils humus is typically destroyed as fast as it is produced, generally yielding MRT ages no older than 300-1000 years, regardless of the true age of the soil.

MUNSELL COLOR NOTATION. Scientific description of color determined by comparing soil to a Munsell Soil Color Chart (Available from Macbeth Division of Kollmorgen Corp., 2441 N. Calvert St., Baltimore, MD 21218). For example, dark yellowish brown is denoted as 10YR3/4m in which the 10YR refers to the hue or proportions of yellow and red, 3 refers to value or lightness (0 is black and 10 is white), 4 refers to chroma (0 is pure black and white and 20 is the pure color), and m refers to the moist condition rather than the dry (d) condition.

OVERBANK DEPOSIT. Fine-grained alluvial sediments deposited from floodwaters outside of the fluvial channel.

OXIC. A soil having a high redox potential. Such soils typically are well drained, seldom being waterlogged or lacking in oxygen. Rubification in such soils tends to increase with age.

PALEO SOIL TONGUE. A soil tongue that formed during a previous soil-forming interval.

PALEOSEISMOLOGY. The study of prehistoric earthquakes through the examination of soils, sediments, and rocks.

PALEOSOL. A soil that formed on a landscape in the past with distinctive morphological features resulting from a soil-forming environment that no longer exists at the site. The former pedogenic process was either altered because of external environmental change or interrupted by burial.

PALINSPASTIC RECONSTRUCTION. Diagrammatic reconstruction used to obtain a picture of what geologic and/or soil units looked like before their tectonic deformation.

PARENT MATERIAL. The great variety of unconsolidated organic and mineral material in which soil forms. Consolidated bedrock is not yet parent material by this concept.

PED. An individual natural soil aggregate, such as a granule, a prism, or a block.

PEDOCHRONOLOGY. The study of pedogenesis with regard to the determination of when soil formation began, how long it occurred, and when it stopped. Also known as soil dating. Two ages and the calculated duration are important:

t_o = age when soil formation or aggradation began, ka

t_b = age when the soil or stratum was buried, ka

t_d = duration of soil development or aggradation, ky

Pedochronological estimates are based on available information. All ages should be considered subject to $\pm$50% variation unless otherwise indicated.

PEDOCHRONOPALEOSEISMOLOGY. The study of prehistoric earthquakes by using pedochronology.

PEDOLOGY. The study of the process through which rocks, sediments, and their constituent minerals are transformed into soils and their constituent minerals at or near the surface of the earth.

PEDOGENESIS. The process through which rocks, sediments, and their constituent minerals are transformed into soils and their constituent minerals at or near the surface of the earth.

PERCOLATION. The downward movement of water through the soil.

pH VALUE. The negative log of the hydrogen ion concentration. Measurements in soils are usually performed on 1:1 suspensions containing one part by weight of soil and one part by weight of distilled water. A soil with a pH of 7.0 is precisely neutral in reaction because it is neither acid nor alkaline. An acid or "sour" soil is one that gives an acid reaction; an alkaline soil is one that gives an alkaline reaction. In words, the degrees of acidity or alkalinity are expressed as:

Extremely acid------- <4.5

Very strongly acid--- 4.5 to 5.0

Strongly acid-------- 5.1 to 5.5

Medium acid---------- 5.6 to 6.0

Slightly acid-------- 6.1 to 6.5

Neutral-------------- 6.6 to 7.3

Mildly alkaline------ 7.4 to 7.8

Moderately alkaline-- 7.9 to 8.4

Strongly alkaline---- 8.5 to 9.0

Very strongly alkaline >9.0

Used if significant:

Very slightly acid--- 6.6 to 6.9

Very mildly alkaline- 7.1 to 7.3

PHREATIC SURFACE. (See Water Table.)

PLANATION. The process of erosion whereby a portion of the surface of the Earth is reduced to a fundamentally even, flat, or level surface by a meandering stream, waves, currents, glaciers, or wind.

PLEISTOCENE. An epoch of geologic time extending from 10 ka to 1.8 Ma; it includes the last Ice Age.

PROFILE, SOIL. A vertical section of the soil through all its horizons and extending into the parent material.

QUATERNARY. A period of geologic time that includes the past 1.8 Ma. It consists of two epochs--the Pleistocene and Holocene.

PROGRADATION. The building outward toward the sea of a shoreline or coastline by nearshore deposition.

RELICT SOIL. A surface soil that was partly formed under climatic conditions significantly different from the present.

RUBIFICATION. The reddening of soils through the release and precipitation of iron as an oxide during weathering. Munsell hues and chromas of well-drained soils generally increase with soil age.

SALINE SOIL. A soil that contains soluble salts in amounts that impair the growth of crop plants but that does not contain excess exchangeable sodium.

SAND. Individual rock or mineral fragments in a soil that range in diameter from 0.05 to 2.0 mm. Most sand grains consist of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

SECONDARY FAULT. A minor fault that bifurcates from or is associated with a primary fault. Movement on a secondary fault never occurs independently of movement on the primary, seismogenic fault.

SHORELINE ANGLE. The line formed by the intersection of the wave-cut platform and the sea cliff. It approximates the position of sea level at the time the platform was formed.

SILT. Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 mm) to the lower limit of very find sand (0.05 mm.) Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

SLICKENSIDES. Polished and grooved surfaces produced by one mass sliding past another. In soils, slickensides may form along a fault plane; at the bases of slip surfaces on steep slopes; on faces of blocks, prisms, and columns undergoing shrink-swell. In tectonic slickensides the striations are strictly parallel.

SLIP RATE. The rate at which the geologic materials on the two sides of a fault move past each other over geologic time. The slip rate is expressed in mm/yr, and the applicable duration is stated. Faults having slip rates less than 0.01 mm/yr are generally considered inactive, while faults with Holocene slip rates greater than 0.1 mm/yr generally display tectonic geomorphology.

SMECTITE. A fine, platy, aluminosilicate clay mineral that expands and contracts with the absorption and loss of water. It has a high cation-exchange capacity and is plastic and sticky when moist.

SOIL. A natural, three-dimensional body at the earth's surface that is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

SOIL SEISMOLOGIST. Soil scientist who studies the effects of earthquakes on soils.

SOIL SLICKS. Curvilinear striations that form in swelling clayey soils, where there is marked change in moisture content. Clayey slopes buttressed by rigid materials may allow minor amounts of gravitationally driven plastic flow, forming soil slicks sometimes mistaken for evidence of tectonism. Soil slicks disappear with depth and the striations are seldom strictly parallel as they are when movement is major. (See also SLICKENSIDES.)

SOIL TECTONICS. The study of the interactions between soil formation and tectonism.

SOIL TONGUE. That portion of a soil horizon extending into a lower horizon.

SOLUM. Combined A and B horizons. Also called the true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

STONELINE. A thin, buried, planar layer of stones, cobbles, or bedrock fragments. Stonelines of geological origin may have been deposited upon a former land surface. The fragments are more often pebbles or cobbles than stones. A stoneline generally overlies material that was subject to weathering, soil formation, and erosion before deposition of the overlying material. Many stonelines seem to be buried erosion pavements, originally formed by running water on the land surface and concurrently covered by surficial sediment.

STRATH TERRACE. A gently sloping terrace surface bearing little evidence of aggradation.

STRUCTURE, SOIL. The arrangement of primary soil particles into compound particles or aggregates that are separated from adjoining aggregates. The principal forms of soil structure are--platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular), and granular. Structureless soils are either single grained (each grain by itself, as in dune sand) or massive (the particles adhering without any regular cleavage, as in many hardpans).

SUBSIDIARY FAULT. A branch fault that extends a substantial distance from the main fault zone.

TECTOTURBATION. Soil disturbance resulting from tectonic movement.

TEXTURE, SOIL. Particle size classification of a soil, generally given in terms of the USDA system which uses the term "loam" for a soil having equal properties of sand, silt, and clay. The basic textural classes, in order of their increasing proportions of fine particles are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sand clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

TOPOSEQUENCE. A sequence of kinds of soil in relation to position on a slope. (See also CATENA.)

TRANSLOCATION. The physical movement of soil particles, particularly fine clay, from one soil horizon to another under the influence of gravity.

UNIFIED SOIL CLASSIFICATION SYSTEM. The particle size classification system used by the U.S. Army Corps of Engineers and the Bureau of Reclamation. Like the ASTM and AASHO systems, the sand/silt boundary is at 80 um instead of 50 um used by the USDA. Unlike all other systems, the gravel/sand boundary is at 4 mm instead of 2 mm and the silt/clay boundary is determined by using Atterberg limits.

VARVE. Lamellae reflecting deposition under seasonal changes in redox conditions. The term “varve,” once used exclusively for glacial lakes, is now used for other fluctuating fresh-water environments as well.

VERTISOL. A soil with at least 30% clay, usually smectite, that fosters pronounced changes in volume with change in moisture. Cracks greater than 1 cm wide appear at a depth of 50 cm during the dry season each year. One of the ten USDA soil orders.

WATER TABLE. The upper limit of the soil or underlying rock material that is wholly saturated with water. Also called the phreatic surface.

WAVE-CUT PLATFORM. The relatively smooth, slightly seaward-dipping surface formed along the coast by the action of waves generally accompanied by abrasive materials.

WEATHERING. All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

WETTING FRONT. The greatest depth affected by moisture due to precipitation.

yr B.P. Uncorrected radiocarbon age expressed in years before present, calculated from 1950. Calendar-corrected ages are expressed in ka, or, if warranted, as A.D. or B.C.

Soil Stratigraphy Study And Relative Age Determinations For A Fault Rupture Hazard Assessment At 10000 Santa Monica Boulevard, Los Angeles, California

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Submitted to:

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August 17, 2012

John Helms, CEG

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Ms. Susan Kirkgard
GEOCON Inc.
3303 North San Fernando Boulevard, Suite 100
Burbank, CA 91504

August 17, 2012

Subject: **Soil Stratigraphy Study And Relative Age Determinations For A Fault Rupture Hazard Assessment At 10000 Santa Monica Boulevard, Los Angeles, California.**

Dear Ms. Kirkgard:

I am pleased to present to you this soil stratigraphic study and relative-age determinations to be used with your fault rupture hazard assessment at 10000 Santa Monica Boulevard, Los Angeles, California. This information presents relative age estimates for the deposits in three locations along a single trench exposure.

Geocon retained John Helms CEG to describe the exposed soil stratigraphy and to assign relative age dates for the deposits identified across the site. Soil descriptions are used to calculate various soil development indices (or SDIs). The SDI values were then compared to the SDI values from similar described soils with known ages to estimate age ranges for the soils understudy.

The attached report classifies each described soil profile, identifies stratigraphic relationships, defines soil chronosequences, and estimates relative age for each soil profile described across the study area. Calculated SDI's show strong correlations to the SDI values of other published, described, and dated soil profiles with similar parent materials. Age estimates range from 83 to 165 ka for the youngest stratigraphic section studied. This deposit is confined to the channel in-filling along the eastern portion of the study area. The oldest stratigraphic section studied for this project ranges in relative age from approximately 208 to 345 ka and is located at the western end of the trench exposure. Please see Table 4 in the attached report for a summary listing of all of the determined relative ages at the study site.

Thank you for this opportunity to be of service. Should you have any questions or require additional information, please do not hesitate to contact me.

Sincerely,

REGISTERED GEOLOGIST
JOHN G. HELMS
No. 2272
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

John Helms, CEG 2272

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Soil Stratigraphy Study And Relative Age Estimates For A Fault Rupture Hazard Assessment At 10000 Santa Monica Boulevard, Los Angeles, California.

Introduction

Three soil profiles have been studied for geomorphic characteristics and relative degrees of weathering to estimate deposit relative-ages. The relative age estimates are based on index value comparisons with other published and dated soil profile descriptions. The comparative soils are from areas with a similar climate and similar parent material to this study area. The estimated relative ages in this report will be used by Geocon to assess the recency and recurrence of faulting across the study area. Alluvial units are assessed chronostratigraphically across a single trench exposure that spans a majority of the project site area. In this study, the soil stratigraphy is defined with soil field description data, and no laboratory data. This study identifies the soil stratigraphy and estimates the relative age of 3 soil profiles. The trench exposure is located across an graded alluvial fan surface.

For the Quaternary geologist, a soil can be defined as a natural body that consists of horizons of organic and/or mineral constituents which differ from it's parent material in some way (Birkland, 1984). A chronosequence is a group of soils for which all soil forming factors (such as topography, parent material, vegetation, and climate) except time is relatively equal (Jenny, 1941). Recent geologic studies in the coastal region of southern California provide age constraints for several deposits and geomorphic surfaces ranging in age from middle Pleistocene to recent (McFadden, 1982; Rockwell, 1988; and WLA, 1998). Often it has proven difficult to date older deposits due to changes in past climatic regimes. Studies on the impacts of glacial to interglacial climatic changes on soil development in specific regions (McFadden, 1982; Birkland, 1984; McFadden, 1988) indicate that soil development has occurred throughout the Quaternary.

This study is concerned with a section of alluvium along the southern range front of the Santa Monica Mountains, which is within the Transverse Ranges Geomorphic Province. A series of stacked and truncated argillic soil subsurface horizons within all of the stratigraphic sections studied indicates that the modified ground surface across the entire study area is old. Ages range from 15 to 30 ka along the eastern portion of the site and from 30 to 70 ka across the central and western portions of the site. The old alluvium is characterized by clay rich, very hard, fine- to medium-grained sand with strong angular blocky ped structure. The soils encountered in this study classify as alfisols that relative age estimates range from 15 to 30 ka at the surface soil in profile 3 (station 270 feet) to 208 to 345 ka at the lowest buried soil in profile 1 (station 46 feet). Soil relative age estimates have broad ranges, dependant upon the pool of comparative data used. The soils across the study area fall into a great group classification (Soil Conservation Service, 2000) of Typic Palexeralfs and Haploxeralfs. Soil profile locations are indicated on the trench logs and geologic map provided with the fault rupture hazard report.

Materials and Methods

Three soil profiles from a single excavator trench were described, sampled, classified, and quantified within the study area. The soils were described in the field, using guidelines set by the Soil Survey Staff (1991 and 1999). Soil horizons were sampled as to prevent contamination from adjacent horizons (Soil Survey Staff, 1991). Sample sizes varied according to the gravel content of the soil horizon. Soil horizons thicker than 2 feet were sampled on a 1-foot interval.

Soil profile field description values quantify soil properties that are used to develop a soil development index (SDI) value as outlined by Harden (1982). Points are assigned to descriptive data for each of several observed soil properties, such as dry color, moist color, texture, structure, dry, moist, and wet consistence, clay film content, and calcium carbonate stage level, for every horizon in a profile relative to the horizon's thickness, and normalized to a common depth. The maturity of a soil profile is gauged through data collected from active wash deposits (or raw alluvium).

Table 1.1 through Table 3.1 lists the soil description for each studied surface in longhand format. Table 1.2 through Table 3.2 lists the soil using soil conservation service notation and shows the SDI calculations. These tables show the calculated SDI values, the soil profile description, and the normalization values for raw alluvium. SDI values are calculated by assigning point values to described soil properties. The points are summed for each soil horizon and divided by the total number of descriptive properties used. This equals the mean horizon index value (HI). HI values are multiplied by the corresponding soil horizon thickness. The SDI value equals the sum of the normalized horizon indices. The maximum horizon index (MHI) is the value of the horizon with the largest summed descriptive value. MHI is independent of horizon thickness, and is usually the diagnostic subsurface soil horizon for most soil profiles. Tables 1.2 through Table 3.2 list all of the determined HI, SDI, and MHI values for the soils under study.

SDI values have shown significant correlations to soil age in many recent studies (Harden, 1981; Rockwell *et al*., 1985; Reheis *et al*., 1990; Rockwell *et al*., 1994). The soils described in this study are compared to soils described and dated by McFadden (1982 and 1987) in San Bernardino County near Mission Creek, by Rockwell (1988) in the Ventura River basin, and by William Lettis and Associates, Inc. (1998) in West Hollywood. SDI values are calibrated to a common depth of 7 feet.

The changes in the subsurface pedogenic properties of the alfisols soil order allows for relative age determinations by emphasizing specific soil properties (such as color and clay film content) that are most diagnostic. Soil properties that express themselves well through time are most often used in the assessment of soil relative ages through a specific soil property index such as the color or clay film index. MHI is a comparison of a soil pedons master (or diagnostic) subsurface horizon (typically an argillic or cambic horizon). Independent of horizon thickness, the MHI directly compares the properties of the soil profiles strongest soil horizon. The color index (Rockwell *et al.,* 1985, 1994) is used to quantify observed colors (in Mussel notation) of each profile in order to compare relative degrees of reddening. The color index is simply the summation of an entire profile's horizon index values for dry colors. The clay film index (Rockwell *et al.,* 1985, 1994) is used to quantify field descriptions of this soil property in order to compare relative profile maturity. The clay film index is simply the summation of an entire soil profile's horizon index values for clay films.

SOIL RELATIVE AGE METHODS

Soil relative ages are calculated and compared independently for each soil profile described. The three soil profiles are located across different alluvial surfaces that differ in relative age, facies of deposition, and degrees of preservation. A series of stacked, buried, and truncated hard, clayey soils with advanced pedogenic structure and illuvial clays characterize all of the soil profiles on this project site.

All of the soil profiles described have a surface age implied by estimating the time of inception for the exposed surficial soil. All of the soils within this study area also contain a stacked or buried series of soils. In this case, a deposit age assessment is obtained by identifying and isolating the different parent materials (or deposits). Then comparing a set of abridged calculated indices to an additional suite of similar soils that have been radiometrically dated yields the equivalent to a surface age estimate. Such burial relationships are common along the southern Santa Monica Mountains range front; especially where soils developed into alluvial fan deposits and buries or locally truncates soils that have developed previously in older alluvial fan sediments. A cumlic soil profile estimated age can assess landform age, and has potential to assess rates of erosion, rates of landform evolution, and rates of tectonic activity across the study area.

Each described soil profile has an SDI value, which is used to estimate the soil relative age. Cumuli relative age estimates for a stacked or buried soil profile are specifically referred to as "deposit ages". The relative age estimate for the surface profile or modern soil is referred to as the "surface age". All of the relative age estimates given are considered minimum ages given that an unknown amount of erosion has occurred after the formation of and before the burial of each truncated soil studied.

DISCUSSION AND RESULTS

This section is broken up by each individual soil profile described. Each section contains a brief write up with tables designated for each soil profile described. The attached Tables 1.1 through 3.1 present the soil profile descriptions in longhand format. Figures 1 through 3 are soil pit illustrations that show the nature of the soil horizon boundaries, physical characteristics of the soil, and views of the related surface morphology. Tables 1.2 through 3.2 present the results of the calculated SDI values. Table 4 is a summary of the soil relative age estimates for each soil profile under study. Table 5 is a compilation of the comparative data in a format that compares to the data generated for this study. Table 6 is a soil abbreviation key to be used in conjunction with the SDI calculation sheets. Table 7 lists the trench log unit relative ages.

Soil descriptions, SDI calculations, and relative age determinations follow for each of the soil profiles studied.

Soil Profile 1
Station 46 Feet

Soil profile 1 is located toward the western portion of the trench at station 46 feet. The soil profile lies across a graded (or stripped) surface that is geomorphically inactive. This soil profile consists of a series of stacked, truncated, and buried argillic soil horizons. Most of the soil horizons observed are well developed and are classified as mature Alfisol remnant soils. Parent materials for these soils consist chiefly of debris flow and/ or stream terrace deposits. This deposit has diagenic mottling (oxidation) and gleying (reduction) that increases at depth and overprints or masks some of the original soil properties (mainly soil color). The soil profile at station 46 contains a surface soil and five buried soils to a depth of approximately 20 feet below the ground surface. This is the oldest stratigraphic section encountered in the study area. A detailed soil description for this profile is listed in table 1.1, the calculated soil development indices for this soil profile and relative age estimates are listed in table 1.2, and the individual soil profile members are briefly described below.

The surface soil profile is classified as a truncated Palexeralf, and is characterized by AB/Bt1 – Bt2 – Cox horizonation. This soil has faint mottling and is slightly reduced. This deposit consists of a fining upwards sequence. Diagnostic properties observed within this soil includes a moderately thick clay and organic rich AB/Bt1 horizon that has common fine and few moderately thick clay films on ped faces and many thick lining pores. This horizon is hard to very hard, very fine-grained with moderately strong angular blocky structure. This grades to an argillic Bt2 subsurface horizon that contains common fine and few moderately thick clay films on ped faces, and is medium to coarse grained with moderately strong prismatic and angular blocky structure. The basal oxidized C-horizon for this surface soil is coarse grained and contains crude internal stratigraphy that forms a scoured contact with the underlying buried soil 1. A relative age estimate of 30 to 70 ka for the surface soil of profile 1 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile S-2 from the Mission Creek soil chronosequence (McFadden, 1988) and the less mature soil from profile Qt5b in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 1 is a severely truncated remnant Alfisol. This soil is characterized by 2Btb1 - 2Btb2/2BCb horizonation. This soil has faint mottling and is weakly reduced. The deposit consists of an fining upwards sequence, and is internally massive and sandy. Diagnostic properties observed within this soil include an argillic 2Btb1 subsurface horizon that has few fine and moderately thick clay films on ped faces, few thick lining pores, and common moderately thick coating clasts. This soil horizon is hard, fine-grained with weak angular blocky structure. This grades to an transitional or argillic 2Btb2/2BCb subsurface horizon that contains very few fine clay films on ped faces, few moderately thick lining pores, and common moderately thick coating clasts. This basal horizon is medium to coarse grained with moderately strong angular blocky structure, and forms a scoured contact with the underlying buried soil 2. A relative age estimate of 15 to 30 ka for buried soil 1 of profile 1 was obtained by comparing the observed clay film development and soil consistence values to more mature soils from profile Qt5-b and the less mature soils from profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 2 is a very thin, weakly developed and truncated remnant Alfisol. This soil is characterized by 3Btb1 - 3BCb horizonation. This soil has weak to strong mottling and is moderately reduced. The deposit consists of a fining upwards sequence. Diagnostic properties observed within this soil include a truncated argillic 3Btb1 subsurface horizon that has few fine clay films on ped faces and few moderately thick lining pores, and is hard, fine-grained with weak angular blocky structure. This grades to an transitional 3BCb subsurface horizon that is medium grained with weak sub angular blocky structure. This basal horizon is internally massive and forms a scoured contact with the underlying buried soil 3. A relative age estimate of 8 to 15 ka for buried soil 2 of profile 1 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil from profile Qt4 and the less mature soil from profile Qt3 in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 3 is a severely truncated remnant Alfisol. This soil is characterized by 4Btb1 – 4Btb2 - 4BCb1 – 4BCb2 horizonation. This soil has weak to strong mottling and is weakly to moderately reduced. The deposit consists of a strong fining upwards sequence. Diagnostic properties observed within this soil include a truncated argillic 4Btb1 subsurface horizon that has few fine and very few moderately thick clay films on ped faces and common moderately thick lining pores, and is very hard, fine-grained with weak to moderately strong angular blocky structure. This grades to an lower argillic 4Bt2b subsurface horizon that has common fine and few moderately thick clay films on ped faces and common moderately thick lining pores, and is hard to very hard, very fine-grained with weak sub angular blocky structure. This grades to a sequence of transitional 4BC1b and 4BC2b subsurface horizons that are sandy and medium grained with weak sub angular blocky structure. This basal horizon sequence is internally massive and forms a scoured contact with the underlying buried soil 4. A relative age estimate of 15 to 30 ka buried soil 3 of profile 1 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil from profile Qt5-b and the less mature soils from profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 4 is a lightly truncated and thick Alfisol remnant within the trench exposure. This soil is characterized by 5ABb/5Btb1 - 5Btb2 – 5Btb3 – 5Btb4/5BCb1 – 5BCb2 – 5BCb3 horizonation. This soil has strong mottling and is moderately strong to strongly reduced. This deposit consists of a fining upwards sequence. Diagnostic properties observed within this soil include a truncated organic rich transitional or argillic 5ABb/5Btb1 subsurface horizon that has many fine and common moderately thick clay films on ped faces and common moderately thick lining pores. This soil is very to extremely hard, fine- to medium grained with moderately strong prismatic and angular blocky structure. This grades to an approximately 6 foot thick sequence of argillic 5Btb2 – 5Btb3 – 5Btb4/5BCb1 subsurface horizons that have common fine and few moderately thick clay films on ped faces and common moderately thick lining pores, and are hard to very hard, very fine to fine-grained with weak to moderately strong angular blocky structure. This grades into a set of transitional 5BCb2 and 5BCb3 subsurface horizons that are sandy and fine to coarse-grained with weak sub angular to angular blocky structure. These basal horizons are internally massive and form a scoured contact into the underlying buried soil 5. A relative age estimate of 70 to 100 ka for buried soil 4 of profile 1 was obtained by comparing the observed clay film development and soil consistence values to the less mature soil profile S-2 in the Mission Creek soil chronosequence (McFadden, 1988) and the more mature soil profile Qof1 in the West Hollywood soil chronosequence (WLA, 1999).

Buried soil 5 is the lowest buried soil observed within this trench exposure, and is possibly the top portion of a lightly truncated Alfisol. This soil is characterized by 6ABb/6Btb1 – 6Btb2 horizonation. This soil has weak to strong mottling, and is strongly reduced. The deposit is massive and dips beneath the trench exposure toward the east. Diagnostic properties observed within this soil include a truncated transitional or argillic 6AB/6Btb1 subsurface horizon that has common fine and moderately thick clay films on ped faces and common fine coating clasts. This soil horizon is slightly hard, fine-grained with weak angular blocky structure. This grades to an lower argillic 6Bt2b subsurface horizon that has common moderately thick and few thick clay films on ped faces and few thick bridging sand grains. This mature subsurface horizon is very to extremely hard, medium-grained with moderately strong to strong angular blocky structure. A relative age estimate of 70 to 100 ka for buried soil 5 of profile 1 was obtained by comparing the observed clay film development and soil consistence values to the less mature soil profile S-2 in the Mission Creek soil chronosequence (McFadden, 1988) and the more mature soil profile Qof1 in the West Hollywood soil chronosequence (WLA, 1999).

In conclusion, the entire stratigraphic section for profile 1 at station 46 feet is estimated to be 208 to 345 ka. Most of this age resides within the lowest two soils (buried soil 4 and 5) of this exposure. The upper five soils (surface soil plus buried soils 1 through 4) within this profile correlate well to the stratigraphic section for profile 2 at station 190. The lowest portion of buried soil number 4 is continuous across the entire trench exposure.

FIGURE 1
Soil Profile 1 at Station 46 feet

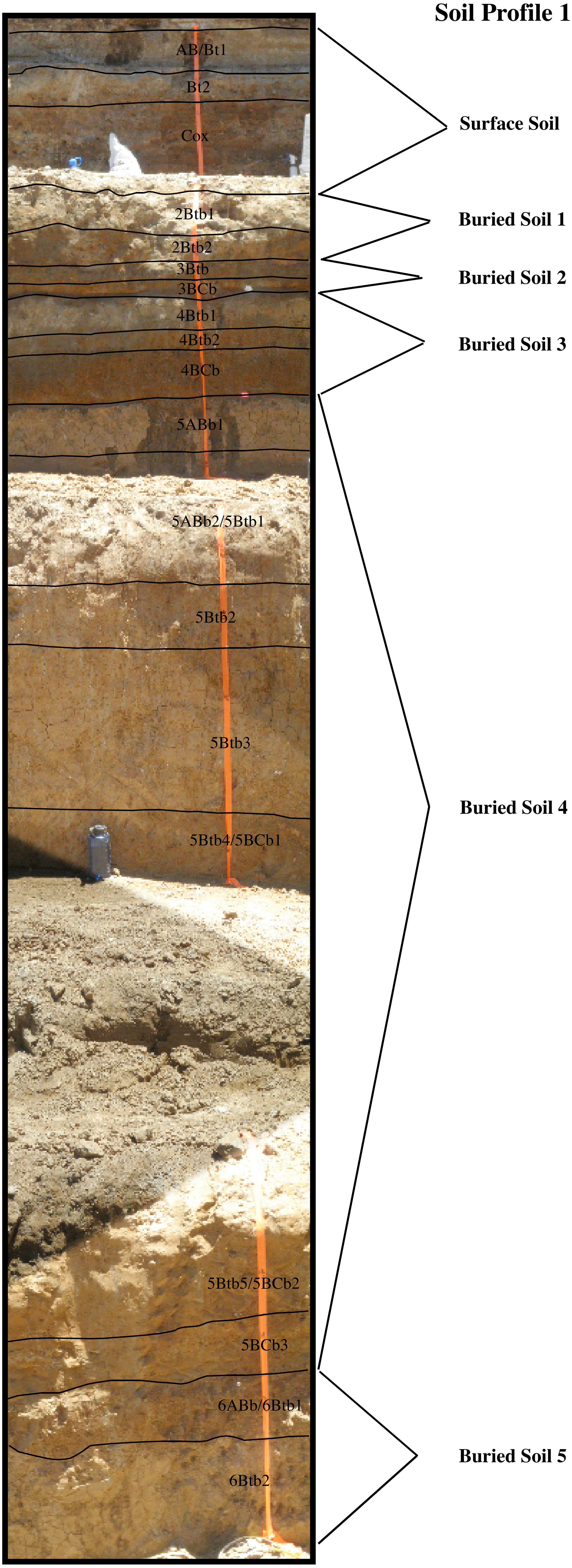

TABLE 1.1 Soil Profile – 1, Station 46 feet.
Geocon Inc.'s Fault Rupture Hazard Study at 10000 Santa Monica Boulevard, Los Angeles, California.

Soil Classification: Truncated and stacked Alfisols
Geomorphic Surface: Alluvial Fan Remnant
Parent Material: Benedict Canyon Alluvium
Vegetation: Urban
Described By: John Helms
Date Described: 6/26/12
Exposure Type: Excavator Trench

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 46 feet
Af	0 -1.1	1.1	Concrete slab, base material, and artificial fill; not described.
AB / Bt1 trun	1.1 – 2.0	1.9	Pale brown (10YR 6/3 d; 10YR 4/2 m); silty clay; moderately strong fine and medium sub angular and angular blocky; hard to very hard, very firm, moderately to very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10 4/3 m) clay films common thin and few moderately thick on ped faces, and common thick lining pores; very fine-grained very well sorted sand, slight organics; 0 - 5 % fine sub rounded and rounded gravel; few medium pores; calcium carbonate stage 1, few fine nodules and faint coatings on few ped faces; localized strong MnO webbing common on ped faces; few fine faint brownish yellow (10YR 6/6 d; 10YR 4/6 m) mottles, weak light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; clear wavy boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 46 feet (Cont.)
Bt2 / BC1	2.0 – 2.6	0.6	Light yellowish brown (10YR 6/4 d; 10YR 4/3 m); loam; weak to moderately strong fine and medium prismatic and angular blocky; hard, friable to firm, moderately sticky, moderately plastic; pale brown (10YR 6/3 d; 10YR 4/2 m) clay films few thin on ped faces, common moderately thick lining pores, and common thin coating clasts; medium-grained moderately well sorted sand, slightly well oxidized; 0 - 5% fine rounded and sub rounded gravel; few medium pores; calcium carbonate stage 1-, few very fine and fine nodules and faint coatings on few ped faces; common fine faint yellowish brown (10YR 5/6 d; 10YR 3/4 m) mottles, weak light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; gradational wavy boundary to:
BC2 / Cox	2.6 – 4.05	1.45	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); loamy sand; single grained to weak very fine sub angular blocky; loose to soft, very friable, non-sticky, non-plastic; clay stains on clasts; coarse-grained poorly sorted sand, slightly oxidized; 10 - 25% fine rounded and sub rounded gravel; crudely stratified scour deposit, truncates underlying deposit; abrupt wavy boundary to:
2Btb1	4.05 – 5.25	1.2	Brown to yellowish brown (7.5 to 10YR 5/4 d; 7.5 to 10YR 3/3 m); sandy loam to loam; weak fine and medium angular and sub angular blocky; hard, friable, slightly sticky, non-plastic; brown (7.5YR 4/4 d; 7.5YR 3/3 m) clay films few thin and very few moderately thick on ped faces, common moderately thick lining pores, and common moderately thick coating clasts; fine-grained well sorted sand, moderately well oxidized; 5 - 10% fine rounded gravel; common coarse faint, brown (7.5YR 5/4 d; 7.5YR 4/3 m) mottles; weak pale brown (10YR 6/3d; 10YR 4/2 m) gleying; gradational wavy boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 46 feet (Cont.)
2Btb2 / 2BCb	5.25– 5.65	0.4	Pale brown (10YR 6/3 d; 10YR 4/3 m); loam; weak to moderately strong fine and medium sub angular and angular blocky; hard to very hard, friable, moderately sticky, slightly to moderately plastic; light yellowish brown (10YR 6/4 d; 10YR 5/4 m) clay films very few thin on ped faces, common thin lining pores, and common thin coating clasts; medium-grained moderately well sorted sand, slightly oxidized; 0 - 5% fine rounded and sub rounded gravel; few coarse moderately strong, strong brown (10Y6/6 d; 10YR 5/4 m) mottles; weak light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; internally massive scour deposit, truncates underlying deposit; clear wavy boundary to:
3Btb1 trun	5.65– 5.95	0.3	Light yellowish brown (10YR 6/4 d; 10YR 4/3 m); silty loam; weak fine sub angular blocky; hard, firm, slightly to moderately sticky, moderately plastic; light pale brown (10YR 6/3 d; 10YR 4/3 m) clay films few thin on ped faces, common thin lining pores; very fine-grained very well sorted sand, slightly oxidized; 0 - 3% fine rounded gravel; few medium pores; calcium carbonate stage 1, few fine nodules and veinlets; common coarse, strong, brown to strong brown (7.5YR 5-6/6 d; 7.5YR 4/4 m) mottles, and moderate light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; gradational wavy boundary to:
3BCb	5.95 – 6.15	0.2	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); sandy loam to loamy sand; single grained to weak very fine sub angular; slightly hard to hard, friable, non- to slightly sticky, non-plastic; clay films few very thin on ped faces and few stains coating clasts; medium-grained moderately well sorted sand, slightly oxidized; 5 - 10% fine rounded gravel; few medium pores; calcium carbonate stage 1, few fine nodules and faint coatings on few ped faces; common fine MnO nodules; few to common coarse, faint, brown to strong brown (7.5YR 5-6/6 d; 7.5YR 4/4 m) mottles; slight light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; internally massive scour deposit, truncates underlying deposit; abrupt wavy boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 46 feet (Cont.)
4Btb1 trun	6.15 – 6.6	o.45	Pale brown (10YR 6/3 d; 10YR 4/2 m); silty clay loam to clay loam; weak to moderately strong fine and medium sub angular and angular blocky; very hard, very firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 5/3 m) clay films few thin and very few moderately thick on ped faces, common moderately thick lining pores; fine-grained well sorted sand; 0 - 3% fine rounded gravel; common fine and few medium pores; common coarse faint, reddish yellow (7.5YR 6/6 d; 7.5YR 4/6 m) mottles, and moderately strong, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; gradational wavy boundary to:
4Btb2	6.6 – 6.85	0.25	Light yellowish brown (10YR 6/4 d; 10YR 4/3 m); silty clay; massive to weak fine sub angular blocky; hard to very hard, very firm, very sticky, very plastic; brownish yellow (10YR 6/6 d; 10YR 5/4 m) clay films common thin and few moderately thick on ped faces, common moderately thick lining pores; very fine-grained very well sorted sand, slightly oxidized; 0 - 3% fine rounded gravel; few fine and medium pores; common fine strong, strong brown (7.5YR 5/6 d; 7.5YR 4/4 m) mottles; weak light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; gradational wavy boundary to:
4BCb1	6.85– 7.55	0.7	Pale brown (10YR 6/3 d; 10YR 4/2 m); sandy loam; single-grained to weak fine sub angular blocky; slightly hard, friable, slightly sticky, non- to slightly plastic; brownish yellow (10YR 6/6 d; 10YR 4/4 m) clay films very few thin on ped faces and very few stains on clasts; medium to coarse-grained moderately well sorted sand; 0 - 5% fine rounded gravel; common coarse faint, brownish yellow (10YR 6/6 d; 10YR 5/4 m) mottles; slight light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; crudely stratified scour deposit; abrupt smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 46 feet (Cont.)
4BCb2	7.55- 8.45	0.9	Grayish brown (10YR 5/2 d; 10YR 3/2 m); sandy clay loam; moderately strong fine and medium prismatic and angular blocky; very to extremely hard, very firm, very sticky, very plastic; pale to light yellowish brown (10YR 6/3-4 d; 10YR 4/3-4 m) clay films many thin and common moderately thick on ped faces; fine to medium-grained moderately well sorted sand, slight organics; 0 - 3% fine rounded gravel; common fine pores; calcium carbonate stage 1--, very few fine nodules; few to common fine weak, brownish yellow (10YR 6/6 d; 10YR 5/4 m) mottles; strong, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; internally massive scour deposit, truncates underlying deposit; abrupt wavy boundary to:
5ABb1 / 5Btb1	8.45- 9.85	1.4	Brown (10YR 5/3 d; 10YR 3/2 m); silty clay; massive to weak very fine and fine sub angular and angular blocky; hard, firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces, and common moderately thick lining pores; very fine-grained very well sorted sand, slight organics; 0 - 3% fine rounded gravel; few fine and medium pores; fine MnO webbings on few ped faces; common fine strong, reddish yellow (7.5YR 6/6 d; 7.5YR 5/6 m) mottles; moderate, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; gradational smooth boundary to:
5Btb2	9.85- 10.75	0.9	Light yellowish brown (10YR 6/4 d; 10YR 4/3 m); loam to clay loam; weak to moderately strong fine angular blocky; hard to very hard, friable to firm, moderately to very sticky, very plastic; dark yellowish brown (10YR 4/6 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces, and common moderately thick lining pores; fine-grained well sorted sand, slightly oxidized; 0 - 3% fine rounded gravel; few fine pores; calcium carbonate stage 1-, few fine nodules, and faint coatings on few ped faces; common strong coarse, reddish yellow (7.5YR 6/6-8 d; 7.5YR 4/6 m) mottles; moderate, light gray (10YR 7/2 d; 10YR 4/1 m) gleying; gradational smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 46 feet (Cont.)
5Btb3	10.75-12.95	2.2	Light yellowish brown (10YR 6/4 d; 10YR 4/3 m); clay loam; moderately strong fine and medium angular blocky; very hard, friable to firm, very sticky, very plastic; brownish yellow(10YR 6/6 d; 10YR 4/6 m) clay films common thin and few moderately thick on ped faces, and common moderately thick lining pores; fine-grained well sorted sand, slightly oxidized; 0 - 3% fine rounded gravel; very few fine pores; calcium carbonate stage 1-, few fine nodules; common strong coarse, strong brown (7.5YR 5/8 d; 7.5YR 4/6 m) mottles; strong, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; clear wavy boundary to:
5Btb4 / 5BCb1	12.95-16.05	3.1	Pale brown (10YR 6/3 d; 10YR 4/3 m); loam to clay loam; massive to weak fine angular and sub angular blocky; hard to very hard, friable to firm, moderately to very sticky, moderately plastic; dark yellowish brown (10YR 4/6 d; 10YR 4/4 m) clay films few to common thin and very few moderately thick on ped faces; fine-grained well sorted sand; 0 - 5% fine rounded gravel; few fine and very few medium pores; calcium carbonate stage 1, common fine and few medium nodules, few fine MnO nodules; common coarse faint, reddish yellow (7.5YR 6/6 d; 7.5YR 5/4 m) mottles, and strong, light gray (10YR 7/2 d; 10YR 5/2 m) gleying; gradational wavy boundary to:
5Btb5 / 5BCb2	16.05-17.65	1.5	Light yellowish brown (10YR 6/4 d; 10YR 4/4 m); sandy loam; weak fine and medium sub angular blocky; slightly hard, very friable, slightly sticky, non-plastic; dark yellowish brown (10YR 4/4-6 d; 10YR 4/4 m) clay films very few thin on ped faces and few clay stains on clasts; fine-grained well sorted sand, slightly oxidized; 0 - 5% fine rounded gravel; few fine MnO nodules; common coarse strong, reddish yellow (7.5YR 6/6 d; 7.5YR 5/4 m) mottles, and strong, light gray (10YR 7/2 d; 10YR 5/1 m) gleying; gradational smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 46 feet (Cont.)
5BCb3	17.65-18.25	0.6	Yellowish brown (10YR 5/4 d; 10YR 4/3-4 m); loamy sand to sandy loam; single grained to weak fine sub angular blocky; soft, very friable, slightly sticky, non-plastic; very few clay stains on clasts; fine-grained well sorted sand, slightly oxidized; 0 - 5% fine rounded gravel; calcium carbonate stage 1-, few fine nodules and faint coatings on few ped faces, very few fine MnO nodules; common moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/4 m) mottles, and strong, light gray (10YR 7/2 d; 10YR 5/1 m) gleying; internally massive scour deposit, truncates underlying deposit; abrupt wavy boundary to:
6ABb / 6Btb1 trun	18.25-19.0	0.75	Brown to yellowish brown (10YR 5/3-4 d; 10YR 4/2 m); loam to silty clay loam; weak fine and medium angular and sub angular blocky; slightly hard, firm, moderately to very sticky, moderately plastic; light brown (7.5YR 6/4 d; 7.5YR 4/4 m) clay films common fine and moderately thick on ped faces, and common fine coating clasts; fine-grained well sorted sand; 5 - 10% fine rounded and sub rounded gravel; few fine MnO nodules and common webbing on ped faces; common coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and strong, light gray (10YR 7/1 d; 10YR 5/1 m) gleying; clear wavy boundary to:
6Btb2	19.0-20.3+	1.3+	Yellowish brown (10YR 5/4 d; 10YR 4/4 m); clay loam; moderately strong to strong fine and medium angular and sub angular blocky; very to extremely hard, very firm, very sticky, very plastic; light brown (7.5YR 6/4 d; 7.5YR 4/4 m) clay films common moderately thick and few thick on ped faces, and few thick bridging sand grains; medium-grained moderately well sorted sand, slightly oxidized; 5 - 10% fine rounded and sub rounded gravel; very few fine MnO nodules and webbing on few ped faces; common coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and strong, light gray (10YR 7/1 d; 10YR 5/1 m) gleying; undetermined lower boundary.

TABLE 1.2 - Soil Development Index Calculation Sheet
Soil Profile - 1 at Station 46 Feet

Unit	Thickness (Feet)	Color				Texture		Structure		Consistence				Clav Films		Horizon Values	Mean Hor. Values
		Drv		Moist						Drv		Wet					
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/5*	*sg*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Profile 1																	
AB / Bt1 trun	0.9	10YR 6/3	0.2	10Y R 4/2	0	sic	0.8	2 abk sbk	0.67	h-vh	0.70	s-vs, p	0.75	3kpo, 2fpf, 1dpf	0.8	0.56	0.50
Bt2 / BC1	0.6	10YR 6/4	0.3	10YR 4/3	0	l	0.6	1 pr, 2 abk	0.67	h	0.6	s, p	0.67	3dpo, 1fpf, 2fcl	0.667	0.50	0.30
BC2 / Cox	1.45	10YR 5/4	0.3	10YR 4/3	0	ls	0.2	1 abk	0.50	lo-so	0.1	so, po	0.00	v1vncl	0.133	0.18	0.26
2Btb1	1.2	10-7.5YR 5/4	0.35	10-7.5YR 3/3	0.05	sl-l	0.5	1 abk sbk	0.50	h	0.6	ss, po	0.17	1kpo, 2dpo, 1fpf, v1dpf,	0.733	0.41	0.50
2Btb2 / 2BCb	0.4	10YR 6/3	0.2	10YR 4/3	0	l	0.6	1-2 abk	0.67	h-vh	0.7	s, ps-p	0.58	v1fppf, 1dpo, 2fpo, 2fcl	0.577	0.48	0.19
3Btb1 trun	0.3	10YR 6/4	0.3	10YR 4/3	0	sil	0.8	1 sbk	0.33	h	0.6	ss-s, p	0.58	1fpf, 2fpo	0.383	0.43	0.13
3BCb	0.2	10YR 5/4	0.3	10YR 3/3	0	l-sl	0.5	1 abk	0.5	sh-h	0.5	so-ss, po	0.08	v1fpf, 1vncl	0.3	0.31	0.06
4Btb1 trun	0.45	10YR 6/3	0.2	10YR 4/2	0	cl-scl	0.8	1-2 sbk abk	0.58	vh	0.8	vs, vp	1	1fpf, v1dpf, 2dpo	0.55	0.56	0.25
4Btb2	0.25	10YR 6/4	0.3	10YR 4/3	0	sic	0.8	1 sbk	0.33	h-vh	0.7	vs, vp	1	2fpf, 1dpf, 2dpo	0.65	0.54	0.14
4BCb1	0.7	10YR 6/3	0.2	10YR 4/2	0	sl	0.4	1 sbk	0.33	sh	0.4	ss, po-ps	0.25	v1fpf, v1vncl	0.283	0.27	0.19
4BCb2	0.9	10YR 5/2	0.1	10YR 3/2	0	cl	0.8	2 pr abk	0.83	vh-eh	0.9	vs, vp	1	3fpf, 2dpf	0.667	0.61	0.55
5ABb/ 5Btb1 trun	1.4	10YR 5/3	0.2	10YR 3/2	0	sic	0.8	1 abk sbk	0.50	h	0.6	vs, vp	1	**2fpf, 1dpf, 2dpo**	**0.65**	0.54	0.75
5Btb2	0.9	10YR 6/4	0.3	10YR 4/3	0	l-cl	0.7	1-2 abk	0.58	h-vh	0.7	s-vs, vp	0.92	**2fpf, 1dpf, 2dpo**	**0.65**	0.55	0.50
5Btb3	2.2	10YR 6/4	0.3	10YR 4/3	0	cl	0.8	2 pr abk	0.83	vh	0.8	vs, vp	1	2fpf, 1dpf, 1kpo	0.75	0.64	1.41
5Btb4 / 5BCb1	3.1	10YR 6/3	0.2	10YR 4/3	0	l-cl	0.7	1 abk sbk	0.50	h-vh	0.7	s-vs, p	0.92	**1-2fpf, v1dpf**	**0.45**	0.50	1.54
5Btb5 / 5BCb2	1.5	10YR 6/4	0.3	10YR 4/4	0	sl	0.4	1 sbk	0.33	sh	0.4	ss, po	0.17	**v1fpf, 1vncl**	0.233	0.26	0.39
5BCb3	0.6	10YR 5/4	0.3	10YR 4/3-4	0.05	ls-sl	0.5	1 sbk	0.33	so	0.2	ss, po	0.17	**n1nvpf**	**0.2**	0.25	0.15
6ABb / 6Btb1 trun	0.75	10YR 5/3-4	0.25	10YR 4/2	0	l-sicl	0.7	1 abk sbk	0.50	sh	0.4	s-vs, p	0.75	2dpf, 2fpf, 2fcl	0.617	0.46	0.34
6Btb2	1.5	10YR 5/4	0.3	10YR 4/4	0	cl	0.8	2 abk sbk	0.67	vh-eh	0.9	vs, vp	1	1kpf, 1kbr, 2dpf	0.833	0.64	0.97

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.56**	**1.06**	**2.52**	**0.8**	**1.60**	**30 - 70**	**30 - 70**
Buried Soil 1	**0.48**	**0.69**	**3.01**	**0.55**	**1.31**	**15 - 30**	**45 - 100**
Buried Soil 2	**0.43**	**0.19**	**2.67**	**0.6**	**0.68**	**8 - 15**	53 - 115
Buried Soil 3	**0.61**	**1.13**	**3.43**	**0.8**	**2.15**	**15 - 30**	68 - 145
Buried Soil 4	**0.64**	**4.73**	**3.42**	**1.6**	**2.93**	**70 - 100**	138 - 245
Buried Soil 5	**0.64**	**1.31**	**4.07**	**0.55**	**1.45**	**70 - 100**	208 - 345

Soil Profile 2
Station 190 Feet

Soil profile 2 is located near the center of the trench at station 190 feet. The soil profile lies across a graded (or stripped) surface that is geomorphically inactive. Similar to soil profile 1, this soil profile consists of a series of stacked, truncated, and buried argillic soil horizons. Most of the soil horizons observed are well developed and are classified as Alfisol soils. Parent materials for these soils consist chiefly of debris flow and/ or stream terrace deposits. This deposit has mottling and gleying that increases at depth and overprints or masks some of the original soil properties (mainly soil color). The soil profile at station 190 contains a surface soil and five buried soils to a depth of approximately 17 feet below the ground surface. This stratigraphic section tracks the section described at station 46, except a new surface soil in this locality buries the surface soil that is encountered at station 46. Additionally, the soil exposed at the base of the exposure at station 46 is below the trench exposure at station 190 feet. This soil profile contains the oldest surficial deposits across the entire study area. A detailed soil description for this profile is listed in table 2.1, the calculated soil development indices for this soil profile and relative age estimates are listed in table 2.2, and the individual soil profile members are briefly described below.

The surface soil profile is classified as a severely truncated Alfisol, and is characterized by a remnant Bt horizon. This soil is well oxidized and displays 7.5YR mixed soil color hues. The deposit is massive and fine-grained, and may be stacked over buried soil 1. Diagnostic properties observed within this soil are an argillic Bt subsurface horizon that contains many fine and common moderately thick clay films on ped faces and common thick lining pores. This soil horizon is very fine grained with moderately strong angular blocky structure and a clear contact with the underlying buried soil 1. A relative age estimate of 15 to 30 ka for this surface soil in profile 2 was obtained by comparing the observed clay film development and soil consistence values to more the mature soil profile Qt5-b and the less mature soil profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 1 correlates well to the surface soil that was described at station 46 feet, and is classified as a lightly truncated Palexeralf. The horizonation is characterized by a 2ABb/2Btb1 – 2Btb2 – 2Btb3 – 2Btb4/2BCoxb1 – 2Btb5/2BCoxb2 sequence. This soil has faint to moderately strong mottles and is weakly reduced. The deposit consists of a fining upwards sequence. Diagnostic properties observed within this soil include a moderately thick clay and organic rich transitional or argillic 2ABb/2Btb1 horizon that has few fine and very few moderately thick clay films on ped faces, common moderately thick lining pores, and few moderately thick coating clasts. This soil horizon is hard to very hard, very fine-grained with moderately strong angular blocky structure. This grades to a set of argillic Bt subsurface horizons 2Btb2 – 2Btb3 that contain common fine and few to common moderately thick clay films on ped faces and common moderately thick lining pores, and is very fine to fine grained with moderately strong angular blocky structure. This grades into a set of basal oxidized transitional BC horizons 2Btb4/2BCoxb1 – 2Btb5/2BCoxb2 that are fine to medium grained with weak angular blocky structure. These lower two horizons locally contain crude internal stratigraphy that forms a scoured contact with the underlying buried soil 2. A relative age estimate of 30 to 70 ka for buried soil 1 in profile 2 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile S-2 in the Mission Creek soil chronosequence (McFadden, 1988) and the less mature soil profile Qt5b in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 2 correlates well to the buried soil 1 that was described at station 46 feet, and is an severely truncated Alfisol remnant. This soil is characterized by 3Btb1 - 3Btb2/3BCb horizonation. This soil has faint to moderately strong mottling and is weakly reduced. The deposit consists of a thin fining upwards sequence. Diagnostic properties observed within this soil include an argillic 3Btb1 subsurface horizon that has common fine and few moderately thick clay films on ped faces and common moderately thick lining pores. This horizon is hard, very fine-grained with weak angular blocky structure. This grades to an transitional or argillic 3Btb2/3BCb subsurface horizon that contains very few fine clay films on ped faces and coating clasts, and is coarse grained with weak sub angular blocky structure. This basal horizon is crudely bedded and forms a scoured contact with the underlying buried soil 3. A relative age estimate of 15 to 30 ka for buried soil 2 in profile 2 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt5-b and the less mature soil profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 3 correlates to the buried soil 2 that was described at station 46 feet. This soil is a very thin, weakly developed, and severely truncated remnant Alfisol. This soil is characterized by a 4BCoxb horizon. This soil has weak mottling and is moderately reduced. The deposit is massive and sandy. Diagnostic properties observed within this soil include a transitional 4BCoxb subsurface horizon that is fine grained with weak angular blocky structure. This basal horizon is internally massive and forms a scoured contact with the underlying buried soil 4. A relative age estimate of 8 to 15 ka for buried soil 3 in profile 2 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt4 and the less mature soil profile Qt3 in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 4 correlates to the buried soil 3 that was described at station 46 feet. This soil is also a thin and truncated remnant Alfisol that is characterized by 5ABb/5Btb1 – 5Btb2/5BCb horizonation. This soil has moderately strong to strong mottling and is moderately reduced. The deposit consists of a massive to very subtle fining upwards sequence and is overall fine grained. Diagnostic properties observed within this soil include a truncated transitional or argillic subsurface horizon 5ABb/5Btb1 that has common fine and few moderately thick clay films on ped faces and common moderately thick lining pores. This soil horizon is hard, fine-grained with weak angular blocky structure. This grades to a lower transitional or argillic 5Btb2/5BCb subsurface horizon that has few fine clay films on ped faces and common fine lining pores, and is massive, fine grained with weak angular blocky structure. Locally this basal horizon is crudely stratified and forms a scoured contact with the underlying buried soil 5. A relative age estimate of 15 to 30 ka for buried soil 4 profile 2 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt5-b and the less mature soil profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 5 correlates well to the buried soil 4 that was described at station 46 feet, and is a well-developed truncated Alfisol remnant. This soil is characterized by 6Btb1 - 6Btb2

– 6Btb3 – 6Btb4/6BCb1 – 6Btb5/6BCb2 horizonation. This soil has moderately strong to strong mottling and is weakly to moderately reduced. This deposit consists of a fining upwards sequence. Diagnostic properties observed within this soil includes a severely truncated argillic 6Btb1 - 6Btb2 – 6Btb3 subsurface horizon sequence that has common fine and few moderately thick clay films on ped faces and common moderately thick lining pores. These horizons are very to extremely hard, very fine grained with weak to moderately strong angular blocky structure. This grades into a sequence of transitional or weaker argillic 6Btb4/6BCb1 – 6Btb5/6BCb2 subsurface horizons that have very few to few fine clay films on ped faces and few fine lining pores, and are fine-grained with weak sub angular to angular blocky structure. These basal horizons are internally massive and are continuous across the entire trench exposure. A relative age estimate of 70 to 100 ka for buried soil 5 in profile 2 was obtained by comparing the observed clay film development and soil consistence values to the less mature soil profile S-2 in the Mission Creek soil chronosequence (McFadden, 1988) and the more mature soil profile Qof1 in the West Hollywood soil chronosequence (WLA, 1999).

In conclusion, the entire stratigraphic section profile 2 at station 190 feet is estimated to be 168 to 315 ka. Most of this age resides within the lowest soil (buried soil 5) of this exposure. All five of the buried soils within this profile correlate well to the surface and first four buried soils within soil profile 1 at station 46. The lowest portion of buried soil number 5 in soil profile 2 is continuous across the entire trench exposure.

FIGURE 2
Soil Profile 2 at Station 190 feet

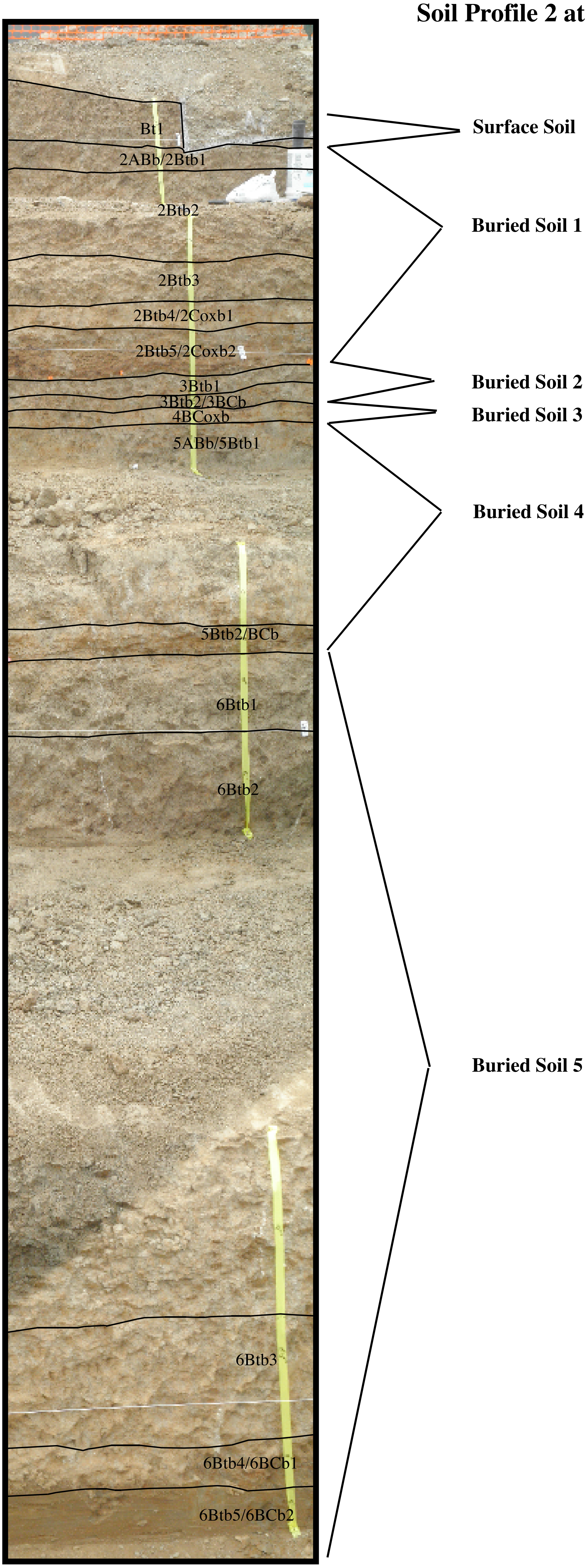

TABLE 2.1 Soil Profile – 2, Station 190 feet.
Geocon Inc.'s Fault Rupture Hazard Study at 10000 Santa Monica Boulevard, Los Angeles, California.

Soil Classification: Series of stacked and truncated Alfisols
Geomorphic Surface: Alluvial Fan Remnant
Parent Material: Benedict Canyon Alluvium
Vegetation: Urban
Described By: John Helms
Date Described: 7/6/12
Exposure Type: Excavator Trench

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 190 feet
Bt trun	0 – 1.2	1.2	Brown (7.5YR 5/4 d; 7.5YR 3/2 m); clay loam; moderately strong medium and coarse angular and sub angular blocky; very hard, firm, very sticky, very plastic; light brown (7.5YR 6/4 d; 7.5YR 4/3 m) clay films many thin and common moderately thick on ped faces and common thick lining pores; very fine-grained very well sorted sand, moderately well oxidized; 0 - 5% fine rounded and sub rounded gravel; few fine and very few medium pores; localized MnO webbing on very few ped faces; common faint coarse reddish yellow (7.5YR 6/6 d; 7.5YR 5/6 m) mottles, weak light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; on-lapping soil unit; clear wavy boundary to:
2ABb / 2Btb1 trun	1.2 – 1.8	0.6	Brown (10YR 5/3 d; 10YR 3/2-3 m); loam to clay loam; weak fine and medium sub angular and angular blocky; hard to very hard, friable to firm, very sticky, moderately to very plastic; brown (7.5YR 5/4 d; 7.5YR 4/3 m) and light yellowish brown (10YR 6/4 d; 10 4/4 m) clay films few thin and very few moderately thick on ped faces, few moderately thick coating clasts, and common moderately thick lining pores; fine-grained well sorted sand, slight organics; 0 - 3 % fine rounded gravel; common fine and few medium pores; localized MnO webbing on very few ped faces; few to common fine faint reddish yellow (7.5YR 6/6 d; 7.5YR 5/6 m) mottles, weak light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; gradational wavy boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 190 feet (Cont.)
2Btb2	1.8 – 3.6	1.8	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); loam; weak to moderately strong fine and medium angular and sub angular blocky; slightly hard to hard, friable, slightly to moderately sticky, slightly plastic; yellowish brown (10YR 5/6 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces and common moderately thick lining pores; fine-grained well sorted sand, slightly well oxidized; 0 - 5% fine rounded gravel; common fine and few medium pores; calcium carbonate stage 1-, common very fine nodules and faint coatings on few ped faces; very few fine faint strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, weak light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; gradational wavy boundary to:
2Btb3	3.6 – 4.4	0.8	Pale brown (10YR 6/3 d; 10YR 4/3 m); clay loam to silty clay; moderately strong fine and medium angular blocky; hard to very hard, very firm, very sticky, very plastic; brownish yellow (10YR 6/6 d; 10YR 4/6 m) clay films common thin, common moderately thick, few thick on ped faces, common moderately thick coating clasts; very fine-grained very well sorted sand; 0 - 3% fine rounded gravel; localized MnO webbing on few ped faces, few coarse moderately strong, reddish yellow (7.5YR 6/6 d; 7.5YR 4/6 m) mottles, localized moderate light gray (10YR 7/2d; 10YR 5/2 m) gleying; clear wavy boundary to:
2Btb4 / 2Coxb1	4.4 – 5.0	0.6	Brown (10YR 5/4 d; 10YR 4/3 m); sandy loam; massive to weak fine and medium angular and sub angular blocky; slightly hard to hard, very friable, slightly sticky, non-plastic; yellowish brown (10YR 5/6 d; 10YR 4/6 m) clay films few thin on ped faces, clay stains on clasts; fine-grained well sorted sand, slightly oxidized; 0 - 3% fine rounded gravel; calcium carbonate stage 1-, faint coatings on few ped faces and lining pores; localized fine MnO coatings on gravel and webbing on ped faces; common coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, strong light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; abrupt wavy boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 190 feet (Cont.)
2Btb5 / 2Coxb2	5.3 – 6.1	0.8	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); sandy loam; massive to weak very fine and fine sub angular and angular blocky; soft to slightly hard, friable, non- to slightly sticky, non-plastic; yellowish brown (10YR 5/6 d; 10YR 4/4 m) clay films very few thin on ped faces, common stains and few thin coating clasts; medium-grained moderately well sorted sand, slightly oxidized; 10 - 25% fine rounded and sub rounded gravel; localized fine MnO coatings on gravel and webbing on ped faces; common coarse faint, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, moderate light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; crudely stratified scour deposit, truncates underlying deposit; abrupt wavy boundary to:
3Btb1 trun	6.1 – 6.45	0.35	Pale brown (10YR 6/3 d; 10YR 4/2 m); silty clay loam; weak fine and medium angular and sub angular blocky; hard, very firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces, common moderately thick lining pores; very fine-grained very well sorted sand; 0 - 3% fine rounded gravel; few fine and medium pores; calcium carbonate stage 1-, few fine and very fine nodules and lining pores; few fine MnO nodules; few fine moderately strong reddish to brownish yellow (7.5-10YR 6/6 d; 7.5-10YR 4/6 m) mottles, and strong light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; gradational wavy boundary to:
3Btb2 / 3BCb	6.45 – 6.7	0.25	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); sandy loam; single grained to weak very fine sub angular and angular blocky; soft, very friable, slightly sticky, non-plastic; yellowish brown (10YR 5/6 d; 10YR 4/4 m) clay films few thin and common stains coating clasts; coarse-grained poorly sorted sand, slightly oxidized; 10 - 25% fine rounded and sub rounded gravel; common fine MnO coatings on gravel and webbing on ped faces; very few fine faint mottles; slight grayish brown(10YR 5/2d; 10YR 4/2 m) gleying; crudely stratified scour deposit, truncates underlying deposit; clear wavy boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 190 feet (Cont.)
4BCoxb trun	6.7 – 7.05	o.35	Pale brown (10YR 6/3 d; 10YR 5/2 m); loam; massive to weak fine angular and sub angular blocky; hard, friable, moderately sticky, moderately plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films very few to few thin and stains on ped faces; fine-grained well sorted sand; 0 - 5% fine rounded gravel; calcium carbonate stage 1, few to common fine and medium nodules and faint coatings on few ped faces; common coarse faint, reddish yellow (7.5YR 6/6 d; 7.5YR 4/4 m) mottles; moderate, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; massive scour deposit, truncates underlying deposit; gradational wavy boundary to:
5ABb / 5Btb1 trun	7.05– 9.05	2.0	Light brownish gray (10YR 6/2 d; 10YR 4/2 m); silty clay loam; weak fine and medium sub angular and angular blocky; hard, firm, moderately to very sticky, very plastic; yellowish brown (10YR 5/4 d; 10YR 4/3 m) clay films common thin and few moderately thick on ped faces, common moderately thick lining pores; fine-grained well sorted sand; 0 - 3% fine rounded gravel; few to common fine and medium pores; calcium carbonate stage 1, few to common fine and very fine nodules and faint coatings on few ped faces; few very fine MnO nodules; common coarse moderately strong, strong to yellowish brown (10-7.5YR 5/6 d; 10-7.5YR 4/4 m) mottles, and moderately strong, light gray (10YR 7/2 d; 10YR 5/2 m) gleying; gradational wavy boundary to:
5Btb2 / 5BCb	9.05– 9.35	0.3	Pale brown (10YR 6/3 d; 10YR 4/2 m); clay loam; massive to weak fine and medium sub angular and angular blocky; very hard, firm, very sticky, very plastic; yellowish brown (10YR 5/4 d; 10YR 4/3 m) clay films few on ped faces, common thin lining pores; fine-grained well sorted sand; 0 - 5% fine sub rounded and rounded gravel; few fine and medium pores; calcium carbonate stage 1, common very fine and fine nodules, faint coatings on few ped faces and lining pores; common coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/4 m) mottles, and strong, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; crudely stratified scour deposit, truncates underlying deposit; clear wavy boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 190 feet (Cont.)
6Btb1 trun	9.35–10.45	1.1	Brown (10YR 5/3 d; 10YR 4/2 m); clay to silty clay; moderately strong fine and medium prismatic and angular blocky; very hard, very firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces, and common moderately thick lining pores; very fine-grained very well sorted sand; 0 - 3% fine rounded gravel; few medium pores; calcium carbonate stage 1-, few very fine and fine nodules; few fine moderately strong, reddish yellow (7.5YR 6/6 d; 7.5YR 4/4 m) mottles; slight, grayish brown (10YR 5/2 d; 10YR 4/2 m) gleying; gradational wavy boundary to:
6Btb2	10.45-14.15	3.7	Brown (10YR 5/3 d; 10YR 4/2 m); clay to silty clay; weak to moderately strong fine and medium prismatic and angular blocky; very to extremely hard, very firm, very sticky, very plastic; brown (7.5YR 5/4 d; 7.5YR 4/4 m) clay films few thin and common moderately thick on ped faces, and few thick lining pores; very fine-grained very well sorted sand; 0 - 3% fine rounded gravel; few medium pores; calcium carbonate stage 1, common fine nodules, faint coatings on few ped faces, and lining pores, strong MnO webbings on few ped faces; common medium moderately strong, reddish yellow (7.5YR 6/6 d; 7.5YR 5/6 m) mottles; slight, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; gradational wavy boundary to:
6Btb3	14.15-15.85	1.7	Light yellowish brown (10YR 6/4 d; 10YR 5/3 m); clay to silty clay; moderately strong fine and medium angular blocky; very hard, very firm, very sticky, very plastic; brownish yellow (10YR 6/6 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces, and common moderately thick lining pores; very fine-grained very well sorted sand, slightly well oxidized; 0 - 3% fine rounded gravel; few medium pores; calcium carbonate stage 1, few fine nodules, and common faint coatings on ped faces; common strong coarse, strong brown (7.5YR 5/8 d; 7.5YR 4/4 m) mottles; moderate, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; gradational smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 190 feet (Cont.)
6Btb4 / 6BCb1	15.85-16.7	0.85	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); loam to silty clay loam; weak fine and medium angular and sub angular blocky; slightly hard, firm, moderately to very sticky, very plastic; brownish yellow (10YR 6/6 d; 10YR 4/4 m) clay films very few thin on ped faces, and few fine lining pores; very fine-grained very well sorted sand, slightly oxidized; 0 - 3% fine rounded gravel; few medium pores; calcium carbonate stage 1--, very few fine and very fine nodules, weak MnO stains on few ped faces; common coarse strong, reddish yellow (7.5YR 6/6 d; 7.5YR 5/6 m) mottles, and strong, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; gradational smooth boundary to:
6Btb5 / 6BCb2	16.7 - 17.3+	0.6+	Brown (10YR 5/3 d; 10YR 4/2 m); silty clay loam; massive to weak fine and medium angular and sub angular blocky; hard, firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films very few thin on ped faces, and few fine lining pores; very fine-grained very well sorted sand; no gravel; very few medium pores; calcium carbonate stage 1--, very few fine nodules; common coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and moderate, light gray (10YR 7/2 d; 10YR 4/2 m) gleying; undetermined lower boundary.

TABLE 2.2 - Soil Development Index Calculation Sheet
Soil Profile - 2 at Station 190 Feet

Unit	Thickness	Color				Texture		Structure		Consistence				Clay Films		Horizon	Mean Hor.
	(Feet)	Dry		Moist						Dry		Wet				Values	Values
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/5*	*sg*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Profile 2																	
Bt trun	1.2	7.5YR 5/4	0.4	7.5YR 3/2	0.1	cl	0.67	2 abk sbk	0.67	vh	0.80	vs, vp	1.00	3fpf, 2dpf, 2dpo	0.767	0.63	0.76
2ABb / 2Btb1 trun	0.6	10YR 5/3	0.2	10YR 3/2	0	l-cl	0.58	1 abk sbk	0.50	h-vh	0.7	vs, p-vp	0.92	1fpf, v1dpf, 2dpo, 1dcl	0.733	0.52	0.31
2Btb2	1.8	10YR 5/4	0.3	10YR 4/3	0	l	0.5	1-2 sbk abk	0.58	sh-h	0.5	ss-s, ps	0.42	2fpf, 1dpf, 2dpo	0.65	0.42	0.76
2Btb3	0.8	10YR 6/3	0.2	10YR 4/2-3	0	cl-sic	0.75	2 abk	0.67	h-vh	0.7	vs, vp	1.00	1kpf, 2dpo, 2dpf, 2fpf	0.933	0.61	0.49
2Btb4 / 2Coxb1	0.6	10YR 5/4	0.3	10YR 4/3	0	sl	0.33	1 abk sbk	0.50	h-vh	0.7	ss, po	0.17	1fpf, 1vncl	0.333	0.33	0.20
2Btb5 / 2Coxb2	0.8	10YR 5/4	0.3	10YR 4/4	0.1	ls-sl	0.25	1 abk sbk	0.5	sh-h	0.5	so-ss, po	0.08	v1fpf, 1fcl	0.333	0.29	0.24
3Btb1 trun	0.35	10YR 6/3	0.2	10YR 4/2	0	sicl	0.83	1 abk sbk	0.5	sh	0.4	vs, vp	1.00	2fpf, 1dpf, 2dpo	0.65	0.51	0.18
3Btb2 / 3BCb	0.25	10YR 5/4	0.3	10YR 4/3	0	sl	0.33	1 abk sbk	0.50	so	0.2	vs, vp	1	v1fpf, 1fcl, 2vncl	0.45	0.40	0.10
4BCoxb trun	0.35	10YR 6/3	0.2	10YR 5/2	0	l	0.5	1 abk sbk	0.50	h	0.6	s, p	0.67	1fpf, 1vfpf	0.383	0.41	0.14
5ABb / 5Btb1 trun	2	10YR 6/2	0.1	10YR 4/2	0	sicl	0.83	1 abk sbk	0.50	h	0.6	s-vs, vp	0.92	2fpf, 1dpf, 2dpo	0.65	0.51	1.03
5Btb2 / 5BCb	0.3	10YR 6/3	0.2	10YR 4/2	0	cl	0.67	1 abk sbk	0.50	vh	0.8	vs, vp	1	1fpf, 2fpo	0.4	0.51	0.15
6Btb1 trun	1.1	10YR 5/3	0.2	10YR 4/2	0	c-sic	0.92	2 pr abk	0.83	vh	0.8	vs, vp	1	**2fpf, 1dpf, 2dpo**	0.65	0.63	0.69
6Btb2	3.7	10YR 5/3	0.2	10YR 4/2	0	c-sic	0.92	1-2 pr abk	0.75	vh-eh	0.9	vs, vp	1	**2fpf, 1dpf, 2dpo**	0.65	0.63	2.34
6Btb3	1.7	10YR 6/4	0.3	10YR 5/3	0	c-sic	0.92	2 abk	0.67	vh	0.8	vs, vp	1	2fpf, 1dpf, 1kpo	0.75	0.63	1.08
6Btb4 / 6BCb1	0.85	10YR 5/4	0.3	10YR 4/3	0	l-sicl	0.58	1 abk sbk	0.50	sh	0.4	s-vs, p	0.75	**v1fpf, 1fpo**	0.333	0.41	0.35
6Btb5 / 6BCb2	0.7	10YR 5/3	0.2	10YR 4/2	0	sicl	0.83	1 abk sbk	0.50	h	0.6	vs, vp	1	**v1fpf, 1fpo**	0.333	0.49	0.35

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.63**	**0.76**	**4.41**	**0.4**	**0.77**	**30 - 70**	**30 - 70**
Buried Soil 1	**0.61**	**1.99**	**3.03**	**1.3**	**2.98**	**30 - 70**	**60 - 140**
Buried Soil 2	**0.52**	**0.28**	**3.25**	**0.5**	**1.10**	**15 - 30**	**75 - 170**
Buried Soil 3	**0.41**	**0.14**	**2.85**	**0.2**	**0.38**	**8 - 15**	**83 - 185**
Buried Soil 4	**0.51**	**1.18**	**3.60**	**0.3**	**1.05**	**15 - 30**	**98 - 215**
Buried Soil 5	**0.63**	**4.80**	**4.17**	**1.2**	**2.72**	**70 - 100**	**168 - 315**

Soil Profile 3
Station 270 Feet

Soil profile 3 is located at the eastern end of the trench at station 270 feet. The soil profile lies across a graded (or stripped) surface that is geomorphically inactive. Similar to soil profiles 1 and 2, this soil profile consists of a series of stacked, truncated, and buried argillic soil horizons. Most of the soil horizons observed are well developed and are classified as mature Alfisol soils. These soils have developed within an in-filled channel or wash that had incised through the soils described in profiles 1 and 2 and then was subsequently backfilled with debris flow and wash deposits. This deposit has mottling and gleying at depth and overprints or masks some of the original soil properties (mainly soil color). The soil profile at station 270 contains a surface soil and six buried soils to a depth of approximately 20.5 feet below the ground surface. This stratigraphic section assesses the relative age of the channel infilling as observed at station 270 feet. The lowest buried and truncated soil within profile 3 correlates well to the subsurface soil horizons observed at the base of soil profile 2 at station 190 feet. A detailed soil description for this profile is listed in table 3.1, the calculated soil development indices for this soil profile and relative age estimates are listed in table 3.2, and the individual soil profile members are briefly described below.

The surface soil profile is classified as a thin, severely truncated, remnant Alfisol. This soil is well oxidized and displays 7.5YR mixed soil color hues. The deposit is massive and medium-grained, and has a scoured contact with the underlying buried soil 1. Diagnostic properties observed within this soil are an argillic Bt subsurface horizon that contains common fine and few moderately thick clay films on ped faces, and common moderately thick lining pores and coating clasts. This soil horizon is slightly hard with moderately strong angular blocky structure. This deposit forms a lightly scoured and clear contact with the underlying buried soil 1. A relative age estimate of 15 to 30 ka for the surface soil remnant in profile 3 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt5-b and the less mature soil profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 1 is classified as a truncated Palexeralf. The horizonation is characterized by a 2Btb1 – 2Btb2 – 2Btb3 argillic horizon sequence. This deposit is massive. Diagnostic properties observed within this soil include a set of argillic Bt subsurface horizons (2Btb1 – 2Btb2 – 2Btb3) that contains common fine and few to common moderately thick clay films on ped faces, few to common moderately thick lining pores, and common moderately thick coating clasts. This soil horizon is very fine to fine grained with weak angular blocky structure. The lower two argillic horizons locally contain crude internal stratigraphy that forms a scoured contact with the underlying buried soil 2. A relative age estimate of 15 to 30 ka for buried soil 1 in profile 3 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt5-b and the less mature soil profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 2 is a severely truncated Alfisol remnant. This soil is characterized by 3Btb argillic horizon. This soil has moderately strong mottling and is moderately reduced. The deposit is massive. Diagnostic properties observed within this soil include an argillic 3Btb subsurface horizon that has few fine and very few moderately thick clay films on ped faces and few moderately thick lining pores. This soil horizon is very to extremely hard, very fine-grained with weak angular blocky structure. This deposit forms a scoured contact with the underlying buried soil 3. A relative age estimate of 8 to 15 ka for buried soil 2 in profile 3 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt4 and the less mature soil profile Qt3 in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 3 is a well-developed and truncated remnant Alfisol. This soil is characterized by a 4ABb1/4Btb1 – 4ABb2/4Btb2 – 4Btb3 horizonation. This soil has moderately strong mottling and is strongly reduced. The deposit is massive and fine-grained. Diagnostic properties observed within this soil include a truncated transitional or argillic subsurface horizon (4ABb1/4Btb1) that has many fine and common moderately thick clay films on ped faces and common moderately thick lining pores. This soil horizon is very hard, very fine-grained with weak angular blocky structure. This grades to a lower set of argillic (4ABb2/4Btb2 – 4Btb3) subsurface horizons that has few to common fine and few moderately thick clay films on ped faces and common moderately thick lining pores, and are massive and fine grained with weak angular blocky structure. The basal horizon of this soil is lightly scoured or stacked onto the underlying buried soil 4. A relative age estimate of 15 to 30 ka for buried soil 3 in profile 3 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil from profile Qt5-b and the less mature soil profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 4 is also a well-developed and truncated remnant Alfisol that is characterized by 5Btb1 – 5Btb2 – 5Btb3 horizonation. This soil has weak to moderately strong mottling and is weakly reduced. The deposit is massive and sandy. Diagnostic properties observed within this soil include a set of argillic subsurface horizons (5Btb1 – 5Btb2 – 5Btb3) that have common to many fine and few to common moderately thick clay films on ped faces and common moderately thick and few thick lining pores. This set of soil horizons are very hard to hard, fine-grained with weak angular blocky structure. The basal argillic horizon of this soil is massive, fine-grained, and is most likely stacked onto the underlying buried soil 5. A relative age estimate of 15 to 30 ka for buried soil 4 in profile 3 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt5-b and the less mature soil profiles Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 5 is a thin and severely truncated remnant Alfisol that is characterized by 6ABb1 – 6Btb1 horizonation. This soil has moderately strong mottling and is weakly to moderately reduced. This deposit consists of a thin coarsening upwards sequence that is internally massive. Diagnostic properties observed within this soil include a truncated transitional or argillic subsurface horizon (6ABb1) that has few fine and very few moderately thick clay films on ped faces and few moderately thick lining pores. This soil horizon is slightly hard, fine-grained with weak angular blocky structure. This grades to a weak argillic (6Btb1) subsurface horizon that has few to common fine and few moderately thick clay films on ped faces and common thin coating clasts, and is hard and fine grained with weak angular blocky structure. The basal horizon of this soil is massive, fine-grained, and is scoured into the underlying buried soil 6. A relative age estimate of 15 to 30 ka for buried soil 5 in profile 3 was obtained by comparing the observed clay film development and soil consistence values to the more mature soil profile Qt5-b and the less mature soil profile Qt4 and Qt5-a in the Ventura Basin soil chronosequence (Rockwell, 1988).

Buried soil 6 correlates well to the basal soil horizons contained within buried soil 5 that was described at station 190 feet and buried soil 4 that was described at station 46 feet. This soil is a severely truncated Alfisol remnant, and is characterized by 7Btb1 - 7Btb2/7BCb1 – 7Btb3/7BCb2 horizonation. This soil has moderately strong to strong mottling and is weakly to moderately reduced. This deposit is massive and fine-grained. Diagnostic properties observed within this soil includes a severely truncated argillic subsurface horizon (7Btb1) that has common fine and few moderately thick clay films on ped faces and is hard, medium grained with weak sub angular blocky structure. This grades into a sequence of transitional or weaker argillic 7Btb2/7BCb1 – 7BCb2 subsurface horizons that are medium to fine-grained with weak sub angular to angular blocky structure. These basal horizons are internally massive and are continuous across the entire trench exposure. A relative age estimate of 70 to 100 ka for buried soil 6 in profile 3 was obtained by comparing the observed clay film development and soil consistence values to the less mature soil profile S-2 in the Mission Creek soil chronosequence (McFadden, 1988) and the more mature soil profile Qof1 in the West Hollywood soil chronosequence (WLA, 1999).

In conclusion, the entire stratigraphic section profile 3 at station 270 feet is estimated to be 153 to 265 ka. Most of this age resides within the lowest soil (buried soil 6) of this exposure. The surface soil plus the first five buried soils within this profile represents the channel fill deposit, and these soils do not directly correlate to the soils described elsewhere within this trench exposure. The soils that infill the channel deposit have a relative age estimate of 83 – 165 ka. The lowest portion of buried soil number 6 is continuous across the entire trench exposure.

FIGURE 3
Soil Profile 3 at Station 270 feet

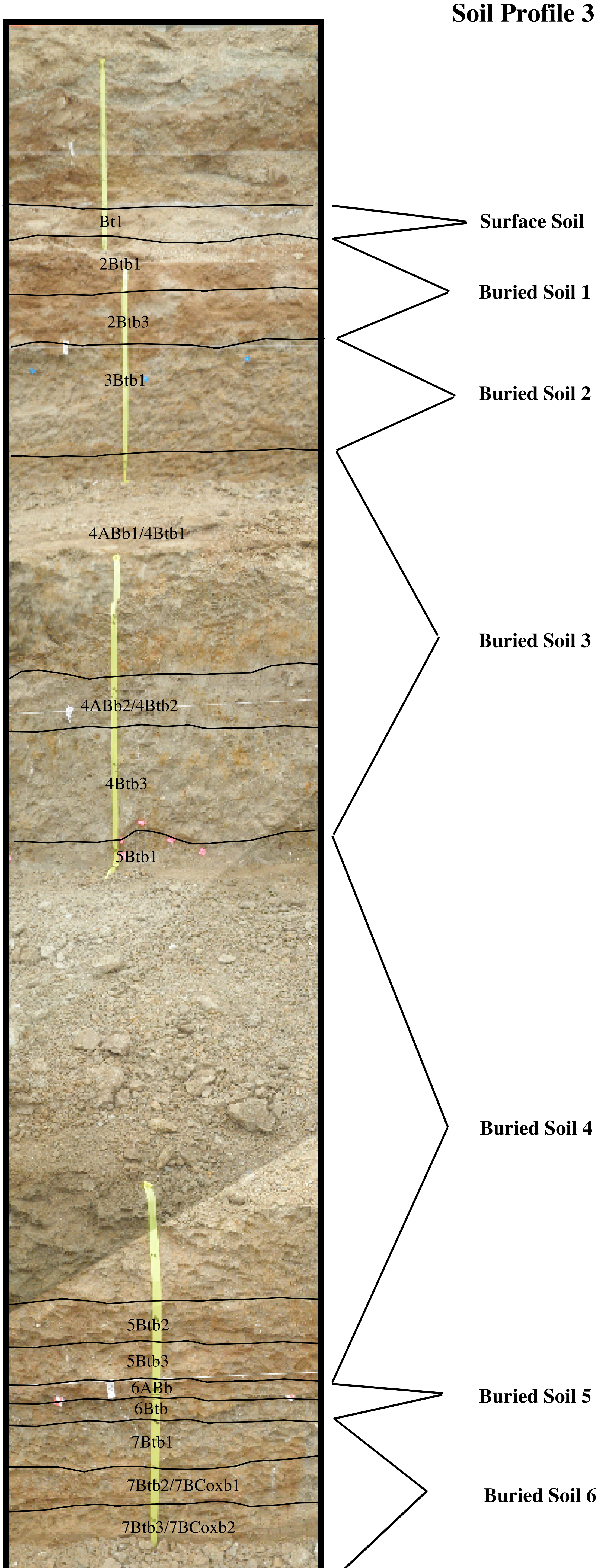

TABLE 3.1 Soil Profile – 3, Station 270 feet.
Geocon Inc.'s Fault Rupture Hazard Study at 10000 Santa Monica Boulevard, Los Angeles, California.

Soil Classification: Series of stacked and truncated Alfisols
Geomorphic Surface: Alluvial Fan Remnant
Parent Material: Benedict Canyon Alluvium
Vegetation: Urban
Described By: John Helms
Date Described: 7/2/12
Exposure Type: Excavator Trench

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 270 feet
Af	0 – 3.8	3.8	Artificial Fill – not described
Bt ox trun	3.8 – 4.3	0.5	Brown (7.5YR 5/4 d; 7.5YR 4/3 m); loam; massive to weak fine angular and medium sub angular blocky; slightly hard, friable, moderately sticky, slightly plastic; strong brown (7.5YR 4/6 d; 7.5YR 3/4m) clay films common thin and few moderately thick on ped faces, few moderately thick and common thin coating clasts, and common moderately thick lining pores; medium-grained moderately well sorted sand; 5 - 10% fine and medium rounded gravel; few medium pores, scour deposit, truncates underlying unit; clear smooth boundary to:
2Btb1 trun	4.3 – 4.7	0.4	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); silty clay loam to silty clay; weak fine angular and sub angular blocky; very hard, firm, very sticky, very plastic; brown (7.5YR 5/3 d; 7.5YR 4/3 m) clay films common thin on ped faces, few moderately thick lining pores; fine-grained well sorted sand, slightly well oxidized; 0 - 3% fine rounded gravel; very few fine and medium pores; very few fine faint strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, weak light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; gradational smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 270 feet (Cont.)
2Btb2	4.7 – 5.9	1.2	Dark yellowish brown (10YR 4/4 d; 10YR 3/3 m); loam; massive to weak very fine and fine angular and sub angular blocky; slightly hard, friable, slightly sticky, non- to slightly plastic; brown (7.5YR 5/4 d; 7.5YR 4/3 m) clay films common thin and moderately thick on ped faces, common thin coating clasts; fine-grained well sorted sand, slightly well oxidized; 10 - 25% fine rounded and sub rounded gravel; localized MnO stains on grains and webbing on very few ped faces, very few fine moderate strong brown (7.5YR 5/6 d; 7.5YR 4/4 m) mottles, localized moderate light gray (10YR 7/2d; 10YR 5/2 m) gleying; locally stratified with sand and pebble lenses; abrupt wavy boundary to:
2Btb3	5.9 – 6.9	1.0	Brown (7.5YR 5/4 d; 7.5YR 4/3 m); loam; single grained to weak very fine sub angular blocky; soft, very friable, non- to slightly sticky, non-plastic; brown (7.5YR 4/4 d; 7.5YR 3/3 m) clay films few to common thin and few moderately thick on ped faces, common thin and few moderately thick coating clasts, and few moderately thick bridging sand grains; coarse-grained poorly sorted sand, moderately well oxidized; 5 - 10% fine rounded gravel; localized MnO stains on grains; locally stratified with sand and pebble lenses; abrupt irregular boundary to:
3Btb1 trun	6.9 – 9.1	2.2	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); silty clay loam; weak fine and medium angular blocky; very hard to extremely hard, very firm, moderately to very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films few thin and very few moderately thick on ped faces, few moderately thick lining pores; very fine-grained very well sorted sand, slightly well oxidized; 0 - 3% fine rounded gravel; few very fine and fine pores; localized fine MnO webbing on ped faces; calcium carbonate stage 1-, faint coatings common on few ped faces; common coarse moderately strong reddish yellow (7.5YR 6/8 d; 7.5YR 5/6 m) mottles, moderate light brownish gray (10YR 6/2d; 10YR 4/2 m) gleying; gradational smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 270 feet (Cont.)
4AB1 / 4Btb1 trun	9.1 – 11.7	2.6	Brown (10YR 5/3 d; 10YR 4/2 m); clay loam; massive to weak fine angular and sub angular blocky; very hard, very firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films many thin and common moderately thick on ped faces, common moderately thick lining pores; very fine-grained very well sorted sand; 0 - 3% fine rounded gravel; few very fine and fine pores; calcium carbonate stage 1-, few fine and very few medium nodules; common fine moderately strong reddish yellow (7.5YR 6/8 d; 7.5YR 5/6 m) mottles, and very weak gleying; clear wavy boundary to:
4AB2 / 4Btb2	11.7– 12.6	0.9	Grayish brown (10YR 5/2 d; 10YR 4/1 m); clay loam; massive to weak fine and medium angular blocky; very hard, firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films few thin and very few moderately thick on ped faces, few moderately thick lining pores; fine-grained well sorted sand, slight organics; 0 - 3% fine rounded gravel; few fine and medium pores; calcium carbonate stage 1-, very few very fine nodules and common lining pores; few fine moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/4 m) mottles, and strong, light gray (10YR 7/1 d; 10YR 5/1 m) gleying; gradational wavy boundary to:
4Btb3	12.6– 14.6	2.0	Light grayish brown (10YR 6/2 d; 10YR 4/1 m); clay loam; massive to weak fine and medium angular blocky; hard to very hard, firm, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces, few moderately thick lining pores; fine-grained well sorted sand; 0 - 3% fine rounded gravel; few medium pores; calcium carbonate stage 1, few to common fine nodules; few to common medium moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/4 m) mottles, and strong, light gray (10YR 7/1 d; 10YR 5/1 m) gleying; abrupt irregular boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 270 feet (Cont.)
5Btb1 trun	14.6– 16.2	1.6	Brown to yellowish brown(10YR 5/3-4 d; 10YR 3/2 m); loam to clay loam; weak to moderately strong medium and coarse angular blocky; very hard, firm, very sticky, moderately to very plastic; brownish yellow (10YR 6/6 d; 10YR 5/6 m) clay films common thin, common moderately thick, and very few thick on ped faces, common moderately thick lining pores; fine-grained well sorted sand, slightly oxidized; 0 - 5% fine rounded gravel; few medium pores; calcium carbonate stage 1, few fine and very fine nodules and common lining pores; few fine to medium moderately strong, strong brown (7.5YR 5/8 d; 7.5YR 4/6 m) mottles, and weak, grayish brown (10YR 5/2 d; 10YR 4/2 m) gleying; gradational smooth boundary to:
5Btb2	16.2– 16.9	0.7	Yellowish brown (10YR 5/4 d; 10YR 3/3 m); loam; massive to weak fine angular blocky; hard, firm, moderately sticky, moderately plastic; brownish yellow (10YR 6/6 d; 10YR 5/6 m) clay films many thin and common moderately thick on ped faces, common moderately thick coating clasts and lining pores; fine-grained well sorted sand, slightly oxidized; 0 - 5% fine rounded gravel; few medium pores; calcium carbonate stage 1, few fine nodules and lining few pores; few to common fine to medium moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and weak, grayish brown (10YR 5/2 d; 10YR 4/2 m) gleying; gradational smooth boundary to:
5Btb3	16.9– 17.5	0.6	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); silty clay loam to silty clay; massive to weak fine and medium angular blocky; hard, very firm, very sticky, very plastic; yellowish brown (10YR 5/6 d; 10YR 4/6 m) clay films common thin and few moderately thick on ped faces, common fine and few moderately thick coating clasts and common moderately thick lining pores; very fine-grained very well sorted sand, slightly oxidized; 0 - 5% fine rounded gravel; few medium pores; calcium carbonate stage 1, common fine nodules, faint coatings on few ped faces, and lining few pores; few medium faint strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and very slight, gleying; gradational smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 270 feet (Cont.)
6AB trun	17.5- 17.8	0.3	Yellowish brown (10YR 5/4 d; 10YR 4/3 m); loam; massive to weak fine sub angular and angular blocky; slightly hard, friable, slightly to moderately sticky, slightly plastic; light yellowish brown (10YR 6/4 d; 10YR 4/4 m) clay films few thin and very few moderately thick on ped faces, few fine coating clasts and few moderately thick lining pores; fine-grained well sorted sand, slightly oxidized; 0 - 5% fine rounded gravel; common medium pores; calcium carbonate stage 1-, few very fine nodules; common coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and very slight, gleying; localized zones with few fine MnO nodules; gradational wavy boundary to:
6Btb1	17.8- 18.25	0.45	Brown to yellowish brown(10YR 5/3-4 d; 10YR 4/3 m); clay loam to silty clay loam; massive to weak fine and very fine angular blocky; hard, very firm, moderately to very sticky, very plastic; yellowish brown (10YR 5/4-6 d; 10YR 4/4 m) clay films common thin and few moderately thick on ped faces, few thin coating clasts; fine-grained well sorted sand; 0 - 5% fine rounded gravel; few medium pores; calcium carbonate stage 1, few fine and very fine nodules and common lining pores; common coarse moderately strong, strong brown (7.5YR 5/8 d; 7.5YR 4/6 m) mottles, and moderately strong, light gray (10YR 7/2 d; 10YR 4/2 m) gleying; localized zones with few fine MnO nodules; base of channel fill; abrupt wavy boundary to:
7Btb1 trun	18.25- 19.05	0.8	Brown (10YR 5/3 d; 10YR 4/2 m); clay loam to sandy clay loam; massive to weak fine sub angular blocky; hard, friable, very sticky, very plastic; light yellowish brown (10YR 6/4 d; 10YR 5/4 m) clay films few to common thin and very few moderately thick on ped faces; medium-grained moderately well sorted sand; 0 - 5% fine rounded gravel; few medium pores; calcium carbonate stage 1, few fine and very fine nodules and common lining pores; common coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and weak, grayish brown (10YR 5/2 d; 10YR 4-3/2 m) gleying; gradational smooth boundary to:

Horizon	Depth (ft)	Thickness (ft)	Description of T-1, Station 270 feet (Cont.)
7Btb2 / 7BCox1	19.05-19.75	0.7	Dark yellowish brown to brown (7.5-10YR 4/4 d; 7.5-10YR 4/3 m); loam; massive to weak very fine and fine sub angular blocky; hard, friable, moderately to slightly sticky, slightly plastic; yellowish brown (10YR 5/4 d; 10YR 4/4 m) clay films few thin on ped faces and few thin coating clasts; medium-grained moderately well sorted sand, moderately well oxidized; 0 - 3% fine rounded and sub rounded gravel; few fine and medium pores; calcium carbonate stage 1, few fine nodules and common lining pores; common very coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and moderately strong, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; gradational smooth boundary to:
7Btb3 / 7BCox2	19.75-20.65+	0.9+	Yellowish brown (10YR 5/4 d; 10YR 3/3 m); sandy clay loam to clay loam; massive to weak fine and medium angular blocky; hard, firm, very sticky, very plastic; brown (10YR 5/3 d; 10YR 4/3 m) clay films common thin and few to common moderately thick on ped faces; very fine-grained very well sorted sand, slightly oxidized; 0 - 3% fine rounded and sub rounded gravel; few fine and medium pores; calcium carbonate stage 1+, few to common very fine and fine nodules and common lining pores; common to many very coarse moderately strong, strong brown (7.5YR 5/6 d; 7.5YR 4/6 m) mottles, and moderately strong, light brownish gray (10YR 6/2 d; 10YR 4/2 m) gleying; undetermined lower boundary.

TABLE 3.2 - Soil Development Index Calculation Sheet
Soil Profile - 3, at Station 270 Feet

Unit	Thickness	Color				Texture		Structure		Consistence				Clay Films		Horizon	Mean Hor.
	(Feet)	Dry		Moist						Dry		Wet				Values	Values
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/6*	*sg*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Profile 3																	
Bt ox trun	0.5	7.5YR 5/4	0.4	7.5YR 4/3	0.1	l	0.5	1 abk sbk	0.50	sh	0.40	s, ps	0.50	2fpf, 1dpf, 2dpo, 2fcl	0.783	0.45	0.23
2Btb1 trun	0.4	10YR 5/4	0.3	10YR 4/3	0	sicl-sic	0.75	1 abk sbk	0.50	vh	0.8	vs, vp	1.00	2fpf, 2dpo	0.5	0.55	0.22
2Btb2	1.2	10YR 4/4	0.3	10YR 3/3	0	l	0.5	1 sbk	0.33	sh	0.4	ss, po-ps	0.25	1fpf, 1dpf, 2fcl	0.583	0.34	0.41
2Btb3	1	7.5YR 5/4	0.4	7.5YR 4/4	0.2	l	0.5	1 sbk	0.33	h	0.6	ss, po-ps	0.25	1-2fpf, 1dpf, 2fcl, 1dbr	0.733	0.43	0.43
3Btb1 trun	2.2	10YR 5/4	0.3	10YR 4/3	0	sicl	0.67	1 abk	0.50	vh-eh	0.9	s, vp	0.83	1fpf, v1dpf, 1dpo	0.55	0.54	1.18
4AB1 / 4Btb1 trun	2.6	10YR 5/3	0.2	10YR 4/2	0	cl	0.67	1 abk sbk	0.5	vh	0.8	vs, vp	1.00	3fpf, 2mkpf, 1mkpo	0.733	0.56	1.45
4AB2 / 4Btb2	0.9	10YR 5/2	0.1	10YR 4/1	0	cl	0.67	1 abk	0.5	vh	0.8	vs, vp	1.00	1fpf, v1dpf, 1dpo	0.55	0.52	0.47
4Btb3	2	10YR 6/2	0.1	10YR 4/1	0	cl	0.67	1 abk	0.50	h-vh	0.7	vs, vp	1	2fpf, 1dpf, 1dpo	0.633	0.51	1.03
5Btb1 trun ?	1.6	10YR 5/3-4	0.25	10YR 3/2	0	l-cl	0.58	1-2 abk sbk	0.58	vh	0.8	vs, p-vp	0.83	v1kpf, 2fpf, 2dpf, 2dpo	0.867	0.56	0.89
5Btb2	0.7	10YR 5/4	0.3	10YR 3/3	0	l	0.5	1 abk	0.50	h	0.6	s, p	0.67	2kpf, 3fpf, 2dpf, 2dpo	0.917	0.50	0.35
5Btb3	0.6	10YR 5/4	0.3	10YR 4/3	0	sicl-sic	0.75	1 abk	0.50	h	0.6	vs, vp	1	2fpf, 1dpf, 2dpo, 2fcl	0.783	0.56	0.34
6ABb trun	0.3	10YR 5/4	0.3	10YR 4/3	0	l	0.5	1 abk sbk	0.50	sh	0.4	ss-s, ps	0.42	**1fpf, v1dpf, 1dpo, 1fcl**	0.567	0.38	0.12
6Btb	0.45	10YR 5/3-4	0.25	10YR 4/3	0	cl-sicl	0.75	1 abk	0.50	h	0.6	s-vs,vp	0.83	**2fpf, 1dpf, 1fcl**	0.55	0.50	0.22
7Btb1 trun	0.8	10YR 5/3	0.3	10YR 4/2	0	scl-cl	0.75	1 sbk	0.33	h	0.6	vs, vp	1	1-2fpf, 1dpf, 2fcl, 1dbr	0.75	0.53	0.43
7Btb2 / 7BCox1	0.7	10-7.5YR 4/4	0.2	10-7.5YR 4/3	0.06	scl-cl	0.75	1 sbk	0.33	h	0.6	vs, vp	1	**1fpf, 1fcl**	0.35	0.47	0.33
7Btb3 / 7BCox2	0.9	10YR 5/4	0.3	10YR 3/3	0	scl-cl	0.76	1 abk	0.50	h	0.6	vs, vp	1	**2fpf, 1-2dpf**	0.483	0.52	0.47

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.45**	**0.23**	**3.18**	**0.4**	**0.78**	**15 - 30**	**15 - 30**
Buried Soil 1	**0.55**	**1.06**	**2.84**	**1**	**1.82**	**15 - 30**	**30 - 60**
Buried Soil 2	**0.56**	**1.18**	**3.75**	**0.3**	**0.55**	**8 - 15**	**38 - 75**
Buried Soil 3	**0.52**	**2.94**	**3.75**	**0.4**	**1.92**	**15 - 30**	**53 - 105**
Buried Soil 4	**0.56**	**1.58**	**3.81**	**0.85**	**2.57**	**15 - 30**	**68 - 135**
Buried Soil 5	**0.50**	**0.34**	**3.16**	**0.55**	**1.12**	**15 - 30**	**83 - 165**
Buried Soil 6	**0.53**	**1.22**	**3.57**	**0.8**	**1.58**	**70 - 100**	**153 - 265**

CONCLUSIONS

The soils observed across the study area are alfisols that have developed in alluvial environments. All three of the soil profiles consist of a series of stacked, truncated, and buried argillic soil horizons. The soil profiles across the western and central portions of the project site area are laterally continuous, and dip gently to the east. Lateral variability in soils across the eastern portion of the site is due to the infilling of an ancient channel scour. In this sedimentological environment surfaces that have been stable long enough to form a robust soil, can suddenly be buried by a new deposit, or scoured out (truncated) and possibly in-filled with younger material. The amount of erosion that has occurred with each truncated soil under study is unknown. Thus the relative age estimates given in this study are minimum ages.

The truncated and buried soils with argillic sub surface soil horizons are moderately well to strongly developed. The buried alfisol soils typically have 10 YR colors with a moderate amount of secondary (pedogenic) clay in a series of argillic (Bt) diagnostic subsurface horizons. Structure is typically moderately strong sub angular to angular blocky and very hard. Clay films are abundant and moderately thick. Most of the buried soils contain moderately strong to strong mottling (oxidation) and gleying (reduction) that increases at depth and overprints or masks some of the original soil properties (mainly soil color).

These soil relative age determinations are consistent with the general geologic and pedogenic observations of soils in southern California. Strongly developed, well horizonated, thick, and oxidized alfisols can be as much as 200 ka in age. Erosion tends to act as a rejuvenating aspect in soil development, by decreasing the strength of the soil development properties consequent age estimates are younger. In that past magnitudes and rates of erosion is difficult to assess the soil relative age estimates are utilized as minimum ages.

The soils exposed in trench exposure are Pleistocene in age. The stacked soils display soil horizons that have strong argillic horizon development. The stratigraphic section for profile 1 at station 46 feet is estimated to be 208 to 345 ka. Most of this age resides within the lowest two soils (buried soil 4 and 5) of this exposure. The upper five soils (surface soil plus buried soils 1 through 4) within this profile correlate well to the stratigraphic section for profile 2 at station 190.

The stratigraphic section profile 2 at station 190 feet is estimated to be 168 to 315 ka. Most of this age resides within the lowest soil (buried soil 5) in this exposure. All five of the buried soils within this profile correlate well to the surface and first four buried soils within soil profile 1 at station 46. The lowest portion of buried soil number 5 in soil profile 2 is continuous across the entire trench exposure.

The stratigraphic section profile 3 at station 270 feet is estimated to be 153 to 265 ka. Most of this age resides within the lowest soil (buried soil 6) of this exposure. The surface soil plus the first four and a portion of the fifth buried soils within this profile represents the channel fill deposit, and these soils do not directly correlate to the soils described elsewhere within this trench exposure. The soils that infill the channel deposit have a relative age estimate of 83 – 165 ka.

LIMITATIONS

The conclusions and recommendations presented herein are the results of an inherently limited scope. Specifically, the scope of services consisted of an assessment of relative age and did not participate in many mapping or logging activities at the site. The conclusions and recommendations contained in this report are professional opinions derived in accordance with current standards of professional practice. No warranty is expressed or implied.

This report has been prepared for the exclusive use of Geocon, Inc. and applies only to the Fault Rupture Hazard Study located at 10000 Santa Monica Boulevard. In the event that significant changes in the interpretations of this study to be made, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed by John Helms, CEG, and the conclusions and recommendations of this report are verified in writing.

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Table 4. Soil Surface Relative-Age Estimates Summary Table

Profile Number	Soil Member	MHI Value	SDI Value	Clay Film	Age (ka)
1	Surface Soil	0.56	2.52	1.60	30 - 70
@sta 46	Buried Soil 1	0.48	3.01	1.31	45 - 100
	Buried Soil 2	0.43	2.67	0.68	53 - 115
	Buried Soil 3	0.61	3.43	2.15	68 - 145
	Buried Soil 4	0.64	3.42	2.93	138 - 245
	Buried Soil 5	0.64	4.07	1.45	208 - 345
2	Surface Soil	0.63	4.41	0.77	30 - 70
@sta 190	Buried Soil 1	0.61	3.03	2.98	60 - 140
	Buried Soil 2	0.52	3.25	1.10	75 - 170
	Buried Soil 3	0.41	2.85	0.38	83 - 185
	Buried Soil 4	0.51	3.60	1.05	98 - 215
	Buried Soil 5	0.63	4.17	2.72	168 - 315
3	Surface Soil	0.45	3.18	0.78	15 - 30
@sta 270	Buried Soil 1	0.55	2.84	1.82	30 - 60
	Buried Soil 2	0.56	3.75	0.55	38 - 75
	Buried Soil 3	0.52	3.75	1.92	53 - 105
	Buried Soil 4	0.56	3.81	2.57	68 - 135
	Buried Soil 5	0.50	3.16	1.12	83 - 165
	Buried Soil 6	0.53	3.57	1.58	153 - 265

Table 5. Comparison Soil Data Indices Value Summary

(McFadden) Mission Creek Soils	SDI At 7'	MHI	Reddening Index	Clay Film Index
S7 0-1000 yrbp	5.9	0.12	0	0
S5 4-13 ka	10.2	0.3	0.1	0
S4 13-70 ka	31.4	0.37	3.94	7.37
S2 70-250 ka	56.10	0.61	4.80	6.24
S2 250-700 ka	25.70	0.39	6.20	10.31

(Rockwell) Ventura River Basin Soils	SDI At 7'	MHI	Reddening Index	Clay Film Index
Qt3 4 - 8 ka	17	0.17	0.5	0
Qt4 10 -15 ka	27	0.43	2	4
Qt5a 15 – 20 ka	28	0.37	3.5	4.2
Qt5b 30 ka	32	0.46	5	7

(WLA) West Hollywood Buried Soils	SDI At 7'	MHI	Reddening Index	Clay Film Index
Qol1 100 ka	21.4	0.42	1.05	1.99
Qol2 100-300 ka	73.5	0.8	8.2	13.2

TABLE 6. Soil Field Description Abbreviation Key

Texture		Structure		Consistence						Clay Films		Calcium Carbonate	
				Dry		Moist		Wet				(Pedogenic CaCO3)	
S	- sand	m	- massive	l	- loose	vfr	-very friable	so	non stickey	v1	veryfew	sl dis	slightly dissemenated
LS	- laomy sand	sg	- single grained	so	-soft	fr	-friable	ss	slightly stickey	1	few	I	slight coatings common on clast bottoms
SL	- sandy loam	**OR**		sh	-slightly hard	fi	-firm	s	moderately siteckey	2	common	II	moderately thick coatings on clast bottoms; few medium common fine nooduses
L	- loam	1	- weak	h	-hard	vfi	-very firm	vs	very stickey	3	continuous	III	thick coatings common on clast bottoms, common medium nodules, common fine pendants, many fine nodules
CL	- clay loam	2	- moderate	vh	-very hard			**AND**		**AND**		VI	many thick coatings on clasts bottoms common coarse pendants few clasts completely enveloped
SCL	- sandy clay loam	3	- strong	eh	-extremely hard			po	non plastci	vn	stains	V	many thick coatings on clasts bottoms, many coarse pendants common clasts completely enveloped- petrocalcic
C	- clay	**AND**						ps	slightly plastic	n	thin	V+	many thick coatings on clasts bottoms, many coarse pendants many clasts completely enveloped, completely disseminated in matrix - petrocalcic
Si	- silt	vf	- very fine					p	moderately plastic	mk	moderately thick		
SiL	- silt loam	f	- fine					vp	very plastic	k	thick		
SiCL	- silt clay loam	m	- medium							**AND**			
SiC	- silty clay	c	- coarse							cl	coating clasts		
		vc	- very coarse							pf	ped faces		
		AND								br	brodgeing sand grains		
		gr	- granular							po	lining pores		
		pl	- platty										
		pr	-prismatic										
		abk	-angular blockey										
		sbk	- sub angular blockey										

Table 7. Trench Log Unit Correlation Sheet

Trench Log Unit	Soil Profile	Soil Horizon	Age (ka)
1	3	surface soil, buried soil 1	30 - 60
2	3	buried soil 2, 3, and 4	68 - 135
4	1	surface soil	60 - 140
	2	surface soil, buried soil 1	
5	1	buried soil 1 and 2	83 - 185
	2	buried soil 2 and 3	
6	1	buried soil 3	98 - 215
	2	buried soil 4	
7	1	buried soil 4 (upper portion)	138 - 245
	2	buried soil 5 (upper portion)	
	3	buried soil 5	
8	1	buried soil 4 (lower portion)	153 - 245
	2	buried soil 5 (lower portion)	
	3	buried soil 5	
9	1	buried soil 4 (lower portion)	168 - 315
10	1	buried soil 5	208 - 345

Soil Stratigraphy Study And Relative Age Estimates

For A Fault Rupture Hazard Investigation At Westfield Century City Mall, 1801 Avenue Of The Stars, 10250 Santa Monica Boulevard, And 1930 Century Park West, Century City - Los Angeles, California

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Submitted to:

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July 26, 2013

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Ms. Susan Kirkgard
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3303 North San Fernando Boulevard, Suite 100
Burbank, CA 91504

July 26, 2013

Subject: **Soil Stratigraphy Study And Relative Age Estimates For A Fault Rupture Hazard Investigation At Westfield Century City Mall, 1801 Avenue Of The Stars, 10250 Santa Monica Boulevard, And 1930 Century Park West, Century City - Los Angeles, California**

Dear Ms. Kirkgard:

I am pleased to present to you this soil stratigraphic study and relative-age estimates to be used with your fault rupture hazard investigation at the Westfield Century City Mall, in Century City and the City of Los Angeles, California. This information presents relative age estimates for the deposits in six locations along two separate transects of borings.

Geocon retained John Helms CEG to describe and assist in correlations of the soil stratigraphy from continuously cored bore hole samples and to assign relative age dates for the deposits identified across the site. The continuously cored bore hole samples were obtained from two separate transects of borings, transect A (along Avenue Of The Stars) and transect B (along Century Park West). Four boreholes are completely described from transect A and two are completely described from transect B. The soil descriptions are used to calculate various soil development indices (or SDIs). The SDI values were then compared to the SDI values from similar described soils with known ages to estimate age ranges for the soils understudy.

The attached report classifies each described soil profile, identifies stratigraphic relationships, defines soil chronosequences, and estimates relative age for each soil profile described across the study area. Calculated SDI's show strong correlations to the SDI values of other published, described, and dated soil profiles with similar parent materials.

Age estimates range from 58 to 135 ka for the young and thin alluvial stratigraphic section studied along the southern portion of transect A in borings B-5 and B-7. An older and thick alluvial section along the northern portion of Transect A in borings B-1 and B-4 has age estimates that range from 137 – 322 ka in age. This relationship carries across to Transect B where the thickest and older alluvial stratigraphic section is in the northern portion of the Transect in boring B-1 with relative ages ranging from approximately 165 to 371 ka. Along the southern portion of Transect B in boring B-3 a young and thin alluvial stratigraphic section ranges in relative age from approximately 92 to 191 ka.

The uppermost buried soils that can be correlated across the entire length of Transect A are well developed and truncated buried argillic soil profiles that range in relative age from 34 –

127 ka. A similar soil observed in Transect B is possibly exhumed at or near the ground surface and ranges in relate age from 9 – 30 ka. Please see Tables 11 and 14 in the attached report for a summary listing of all of the determined relative ages at the study site.

Thank you for this opportunity to be of service. Should you have any questions or require additional information, please do not hesitate to contact me.

Sincerely,

John Helms, CEG 2272

REGISTERED GEOLOGIST
JOHN G. HELMS
No. 2272
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

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Soil Stratigraphy Study And Relative Age Estimates For A Fault Rupture Hazard Investigation At Westfield Century City Mall, 1801 Avenue Of The Stars, 10250 Santa Monica Boulevard, And 1930 Century Park West, Century City - Los Angeles, California.

INTRODUCTION

Six soil profiles have been studied for geomorphic characteristics and relative degrees of weathering to estimate deposit relative-ages. The relative age estimates are based on index value comparisons with other published and dated soil profile descriptions. The comparative soils are from areas with a similar climate and similar parent material to this study area. The estimated relative ages in this report will be used by GEOCON, Inc. to assess the recency and recurrence of faulting across the study area. Alluvial units are assessed chronostratigraphically across several borehole locations from two separate transects that span a majority of the project site area. In this study, the soil stratigraphy is defined with soil field description data, and no laboratory data. This study identifies the soil stratigraphy and estimates the relative ages of six stacked soil profiles. Four continuously cored and sampled boreholes have been described along Transect A, which is located along Avenue Of The Stars. Two additional continuously cored and sampled boreholes have been described along Transect B, which is located along Century Park West. Both Transects are located along a graded and stripped alluvial surface.

For the Quaternary geologist, a soil can be defined as a natural body that consists of horizons of organic and/or mineral constituents which differ from it's parent material in some way (Birkland, 1984). A chronosequence is a group of soils for which all soil forming factors (such as topography, parent material, vegetation, and climate) except time is relatively equal (Jenny, 1941). Recent geologic studies in the coastal region of southern California provide age constraints for several deposits and geomorphic surfaces ranging in age from middle Pleistocene to recent (McFadden, 1982; Rockwell, 1988; and WLA, 1998). Often it has proven difficult to date older deposits due to changes in past climatic regimes. Studies on the impacts of glacial to interglacial climatic changes on soil development in specific regions (McFadden, 1982; Birkland, 1984; McFadden, 1988) indicate that soil development has occurred throughout the Quaternary.

This study is concerned with a section of alluvium along the southern range front of the Santa Monica Mountains, which is within the Transverse Ranges Geomorphic Province. A series of stacked and truncated argillic soil subsurface horizons within all of the stratigraphic sections studied indicates that the alluvial stratigraphic section across the entire study area is old. The thickness of the alluvial stratigraphic section in both Transects thickens to the north and increases in relative age to the north across the project site area. Age estimates range from 58 to 135 ka for the younger and thinner alluvial stratigraphic section studied along the southern portion of transect A in borings B-5 and B-7. An older and thicker alluvial section along the northern portion of Transect A in borings B-1 and B-4 has age estimates that range from 137 – 322 ka in age. This relationship carries across to Transect B where the thicker and older alluvial stratigraphic section is in the northern portion of the Transect in boring B-1 has relative age estimates that range from 165 to 371 ka. Along the southern portion of

Transect B in boring B-3, a younger and thinner alluvial stratigraphic section ranges in relative age from 92 to 191 ka.

The old alluvium is characterized by clay rich, hard to very hard, very fine-grained sand that is plugged with illuvial clay. Most of the surface soils encountered in this study classify as Alfisols, and relative age estimates range from 8 to 15 ka at the surface across a majority of the project site area. In the northern portion of the study area the surface soils encountered classify as Entisols and relative age estimates range from 1 to 8 ka for these surface soils. Soil relative age estimates have broad ranges, dependant upon the pool of comparative data used. Most of the buried soils across the study area fall into a great group classification (Soil Conservation Service, 2000) of Typic Haploxeralfs. Soil profiles were described from borings B-1, B-4, B-5, and B-7 in Transect A and from borings B-1 and B-3 in Transect B.

MATERIALS AND METHODS

Initial feasibility studies were carried out for this study by examining previously drilled continuous core samples by AMEC. AMEC Borings B-2, B-3, and B-8 along Transect A, and AMEC borings B-5, B-6, and B-7 along Transect B were reviewed on 6/12 - 13/2012 for the presence and continuity of soils. Although no detailed descriptions were generated from the AMEC core samples, the summary logs generated indicate that significant stratigraphic correlations may be present across the site.

Additional continuous core samples collected by GEOCON, Inc. were described in more detail. Four soil profiles from were described out of core samples from Transect A in GEOCON borings B-1, B-4, B-5, and B-7. Two additional soil profiles from were described out of core samples from Transect B in GEOCON borings B-1 and B-3. The soils were described using guidelines set by the Soil Survey Staff (1991 and 1999). Specific soil properties such as soil structure and soil horizon boundaries could not be accurately described the from core sample exposures. Thus, these soil qualifiers have not been described and do not factor into the estimated soil relative age comparisons.

Soil profile field description values quantify soil properties that are used to develop a soil development index (SDI) value as outlined by Harden (1982). Points are assigned to descriptive data for each of several observed soil properties, such as dry color, moist color, texture, dry, moist, and wet consistence, and clay film content, for every horizon in a profile relative to the horizon's thickness, and normalized to a common depth. The maturity of a soil profile is gauged through data collected from active wash deposits (or raw alluvium).

Table 1.1 through Table 4.1 and Table 7.1 to 8.1 list the soil description for each studied boring in longhand format. Table 1.2 through Table 4.2 and Table 7.2 to 8.2 list the soil using soil conservation service notation and shows the SDI calculations. These tables show the calculated SDI values, the soil profile description, and the normalization values for raw alluvium. SDI values are calculated by assigning point values to described soil properties. The points are summed for each soil horizon and divided by the total number of descriptive properties used. This equals the mean horizon index value (HI). HI values are multiplied by the corresponding soil horizon thickness. The SDI value equals the sum of the normalized horizon indices. The maximum horizon index (MHI) is the value of the horizon with the largest summed descriptive value. MHI is independent of horizon thickness, and is usually the diagnostic subsurface soil horizon for most soil profiles. Table 1.2 through Table 4.2 and Table 7.2 to 8.2 list all of the determined HI, SDI, and MHI values for the soils under study.

SDI values have shown significant correlations to soil age in many recent studies (Harden, 1981; Rockwell *et al.*, 1985; Reheis *et al.*, 1990; Rockwell *et al.*, 1994). The soils described in this study are compared to soils described and dated by McFadden (1982 and 1987) in San Bernardino County near Mission Creek, by Rockwell (1988) in the Ventura River basin, and by William Lettis and Associates, Inc. (1998) in West Hollywood. SDI values are calibrated to a common depth of 7 feet.

The changes in the subsurface pedogenic properties of the alfisols soil order allows for relative age determinations by emphasizing specific soil properties (such as color and clay film content) that are most diagnostic. Soil properties that express themselves well through time are most often used in the assessment of soil relative ages through a specific soil property index such as the color or clay film index. MHI is a comparison of a soil pedons master (or diagnostic) subsurface horizon (typically an argillic or cambic horizon). Independent of horizon thickness, the MHI directly compares the properties of the soil profiles strongest soil horizon. The color index (Rockwell *et al.,* 1985, 1994) is used to quantify observed colors (in Mussel notation) of each profile in order to compare relative degrees of reddening. The color index is simply the summation of an entire profile’s horizon index values for dry colors. The clay film index (Rockwell *et al.,* 1985, 1994) is used to quantify field descriptions of this soil property in order to compare relative profile maturity. The clay film index is simply the summation of an entire soil profile’s horizon index values for clay films.

SOIL RELATIVE AGE METHODS

Soil relative ages are calculated and compared independently for each soil profile described. The six soil profiles are located across different buried alluvial surfaces that differ in relative age, facies of deposition, and degrees of preservation. A series of stacked, buried, and truncated hard, clayey soils with advanced pedogenic structure and illuvial clays characterize all of the buried soil profiles on this project site.

All of the soil profiles described have a surface age implied by estimating the time of inception for the exposed surficial soil. All of the soils within this study area also contain a stacked or buried series of soils. In this case, a deposit age assessment is obtained by identifying and isolating the different parent materials (or deposits). Then comparing a set of abridged calculated indices to an additional suite of similar soils that have been radiometrically dated yields the equivalent to a surface age estimate. Such burial relationships are common along the southern Santa Monica Mountains range front; especially where soils developed into alluvial fan deposits and buries or locally truncates soils that have developed previously in older alluvial fan sediments. A cumlic soil profile estimated age can assess landform age, and has potential to assess rates of erosion, rates of landform evolution, and rates of tectonic activity across the study area.

Each described soil profile has an SDI value, which is used to estimate the soil relative age. Cumuli relative age estimates for a stacked or buried soil profile are specifically referred to as "deposit ages". The relative age estimate for the surface profile or modern soil is referred to as the "surface age". All of the relative age estimates given are considered minimum ages given that an unknown amount of erosion has occurred after the formation of and before the burial of each truncated soil studied.

SOIL SUMMARY DESCRIPTIONS

Soil summary descriptions were generated for most other borings that were not described in detail for this study. The summary descriptions record diagnostic pedogenic features for each soil horizon identified. This was done in order to assist with establishing stratigraphic correlations across the site. Relative age estimates were not generated for any of the listed soil summary descriptions. The soil summary descriptions for the GEOCON borings are listed in Tables 5.1 through 5.3 for Transect A and in Tables 9.1 through 9.4 for Transect B. In addition, the initial soil summary descriptions for the AMEC borings are listed in Tables 6.1 through 6.3 for Transect A and in Tables 10.1 through 10.3 for Transect B

DISCUSSION AND RESULTS

This section is broken up by each individual soil profile described. Each section contains a brief write up for each continuously cored boring described with tables designated for each soil profile. The attached Tables 1.1 through 4.1 and Tables 7.1 to 8.1 present the soil profile descriptions in longhand format. Tables 1.2 through 4.2 and Tables 7.2 to 8.2 present the results of the calculated SDI values. Table 11 is a summary of the soil relative age estimates for each soil profile under study. Table 12 is a compilation of the comparative data in a format that compares to the data generated for this study. Table 13 is a soil abbreviation key to be used in conjunction with the SDI calculation sheets. Table 14 lists the trench log unit relative ages.

Soil descriptions, SDI calculations, and relative age determinations follow for each of the soil profiles studied.

TRANSECT A BORINGS

Four soil profiles from were described out of core samples from Transect A in GEOCON borings B-1, B-4, B-5, and B-7. Age estimates range from 58 to 135 ka for the younger and thinner alluvial stratigraphic section studied along the southern portion of transect A in borings B-5 and B-7. An older and thicker alluvial section along the northern portion of Transect A in borings B-1 and B-4 has age estimates that range from 137 – 322 ka in age.

Boring 1

The core samples from GEOCON Transect A, Boring B-1 were reviewed on site on 5/23/2013. This boring is located on the northern end of Transect A, and is one of the thicker alluvial sections encountered. See Table 1.1 for a complete soil description of the continuously sampled boring, table 1.2 for the SDI index value calculations and relative age estimates, and the GEOCON Inc.'s cross section and geologic map for both the borehole and transect's location.

The surface soil in Transect A at boring B-1 is a weakly developed Entisol that is characterized by juvenile argillic horizon development and has a estimated relative age of 4 – 8 ka. The uppermost buried soils that can be correlated across the entire length of Transect A are buried soil numbers 1 and 2 in boring B-1. These soils are well developed and severely truncated buried argillic soil profiles that range in relative age from 34 – 68 ka. The entire alluvial stratigraphic section in Transect A, boring B-1 has an estimated age that ranges from 156 – 322 ka, and is 95 feet thick. Differences in depths of burial and unit thicknesses due to differential erosion / truncation laterally along Transect A will cause a variance in relative age estimates between the individual borings. In order to control for this multiple soil descriptions were generated across each boring transect which assesses the same buried surfaces at differing depths of burial and in differing states of preservation.

Boring 4

The core samples from GEOCON Transect A, Boring B-4 were reviewed on site on 9/13/2012. This boring is also located on the northern end of Transect A, and is also one of the thicker alluvial sections encountered. See Table 2.1 for a complete soil description of the continuously sampled boring, table 2.2 for the SDI index value calculations and relative age estimates, and the GEOCON Inc.'s cross section and geologic map for both the borehole and transect's location.

The surface soil in Transect A at boring B-4 is a moderately well developed Alfisol that is characterized by a severely truncated and well developed argillic horizon and has a estimated relative age of 8 – 15 ka. The surface soil in boring B-4 is missing from the surface in boring B-1 along Transect A and may have been eroded off to the north. The uppermost buried soils that can be correlated across the entire length of Transect A are buried soil numbers 3 and 4 in boring B-4. These soils are stacked, well developed, and severely truncated buried argillic soil profiles that range in relative age from 58 – 127 ka. The entire alluvial stratigraphic section in Transect A, boring B-4 has an estimated age that ranges from 137 – 295 ka, and is 85 feet thick.

Boring 5

The core samples from GEOCON Transect A, Boring B-5 were reviewed on site on 9/18/2012. This boring is located in the southern portion of Transect A, and is a thin or truncated alluvial section. See Table 3.1 for a complete soil description of the continuously sampled boring, table 3.2 for the SDI index value calculations and relative age estimates, and the GEOCON Inc.'s cross section and geologic map for both the borehole and transect's location.

The surface soil in Transect A at boring B-5 is a moderately well developed Alfisol that is characterized by a severely truncated and well developed argillic horizon and has a estimated relative age of 8 – 15 ka. The surface soil in boring B-5 is similar to the surface soils encountered in borings B-4 and B-7 along Transect A. The uppermost buried soils that can be correlated across the entire length of Transect A are buried soil numbers 2 and 3 in boring B-5. These soils are stacked, well developed, and severely truncated buried argillic soil profiles that range in relative age from 54 – 119 ka. The entire alluvial stratigraphic section in Transect A, boring B-5 has an estimated age that ranges from 58 – 127 ka, and is 50 feet thick.

Boring 7

The core samples from GEOCON Transect A, Boring B-7 were reviewed on site on 9/12/2012. This boring is located at the southern end of Transect A, and is also a thin or truncated alluvial section. See Table 4.1 for a complete soil description of the continuously sampled boring, table 4.2 for the SDI index value calculations and relative age estimates, and the GEOCON Inc.'s cross section and geologic map for both the borehole and transect's location.

The surface soil in Transect A at boring B-7 is also a moderately well developed Alfisol that is characterized by a severely truncated and well developed argillic horizon and has a estimated relative age of 8 – 15 ka. The surface soil in boring B-7 is similar to the surface soils encountered across the entire southern and central portions of Transect A. The uppermost buried soils that can be correlated across the entire length of Transect A are buried soil numbers 3 and 4 in boring B-7. These soils are stacked, well developed, and severely truncated buried argillic soil profiles that range in relative age from 58 – 127 ka. The entire alluvial stratigraphic section in Transect A, boring B-7 has an estimated age that ranges from 62 – 135 ka, and is 47.25 feet thick.

GEOCON BORING SUMMARY DESCRIPTIONS

Soil summary descriptions were generated for most of the other GEOCON borings that were not described in detail for this study. For Transect A the additional soil summary descriptions for the GEOCON borings are listed in Tables 5.1 through 5.3. Relative age estimates were not generated for any of these listed soil summary descriptions. These summary descriptions were generated to assist with establishing stratigraphic correlations across the site. The observations for the soil summary descriptions of borings B-2 and B-4 for Transect A were made on 9/12/2012, and the observations for the soil summary descriptions of boring B-9 for Transect A was made on 5/23/2013. All of the GEOCON borings along Transect A appear to contain artificial fill that is in contact with thin Early Holocene-aged channel scour and stream terrace deposits which overlies a stacked sequence of Pleistocene-aged soils.

AMEC BORING SUMMARY DESCRIPTIONS

The core samples from AMEC borings B-2, B-3, and B-8 along transect 1 were briefly reviewed for soil properties on 6/13/2012. These soil summary descriptions for the AMEC borings are listed in Tables 6.1 through 6.3. The AMEC borings along Transect A all appear to contain artificial fill that is in contact with thin Early Holocene-aged channel scour and stream terrace deposits that overlie Pleistocene-aged soils.

TRANSECT B BORINGS

Two soil profiles from were described out of core samples from Transect B in GEOCON borings B-1 and B-3. Age estimates range from 92 to 191 ka for the younger and thinner alluvial stratigraphic section studied along the southern portion of transect B in boring B-3. An older and thicker alluvial section along the northern portion of Transect B in boring B-1 has an age estimate that ranges from 165 – 321 ka in age.

Boring 1

The core samples from GEOCON Transect B, Boring B-1 were reviewed on site on 5/20/2013. This boring is located on the northern end of Transect B, and is one of the thicker alluvial sections encountered. See Table 7.1 for a complete soil description of the continuously sampled boring, table 7.2 for the SDI index value calculations and relative age estimates, and the GEOCON Inc.'s cross section and geologic map for both the borehole and transect's location.

The surface soil in Transect B at boring B-1 is a weakly developed Entisol that is characterized by severely truncated juvenile argillic horizon development and has a estimated relative age of 1 – 4 ka. The uppermost buried soils that can be correlated across the entire length of Transect B are buried soil numbers 1 and 2 in boring B-1. These soils are well developed and severely truncated buried argillic soil profiles. Combined with the surface soil, buried soil 1 comprises a Early Holocene to Latest Pleistocene alluvial package that ranges in relative age from 9 – 30 ka. Buried soil 2 in boring B-1 for Transect B is a Late Pleistocene truncated alluvial argillic soil that ranges in relative age from 39 – 89 ka. The entire alluvial stratigraphic section in Transect B, boring B-1 has an estimated age that ranges from 165 – 371 ka, and is at least 95 feet thick.

Boring 3

The core samples from GEOCON Transect B, Boring B-3 were reviewed on site on 6/6/2013. This boring is located in the southern portion of Transect B, and is a thin or truncated alluvial section. See Table 8.1 for a complete soil description of the continuously sampled boring, table 8.2 for the SDI index value calculations and relative age estimates, and the GEOCON Inc.'s cross section and geologic map for both the borehole and transect's location.

The surface soil in Transect B at boring B-3 is a weakly developed Alfisol that is characterized by a severely truncated and moderately well developed argillic horizon and has a estimated relative age of 8 – 15 ka. The uppermost buried soils that can be correlated across the entire length of Transect B are buried soil numbers 1 and 2 in boring B-3. These soils are well developed and severely truncated buried argillic soil profiles. Combined with the surface soil, buried soil 1 comprises a Early Holocene to Latest Pleistocene alluvial package that ranges in relative age from 16 – 30 ka. Buried soil 2 in boring B-3 for Transect B is a Late Pleistocene truncated alluvial argillic soil that ranges in relative age from 31 – 60 ka. The entire alluvial stratigraphic section in Transect B, boring B-1 has an estimated age that ranges from 92 – 191 ka, and is 50.2 feet thick.

GEOCON BORING SUMMARY DESCRIPTIONS

Soil summary descriptions were generated for most of the other GEOCON borings that were not described in detail for this study. For Transect B the additional soil summary descriptions for the GEOCON borings are listed in Tables 9.1 through 9.4. Relative age estimates were not generated for any of these listed soil summary descriptions. These summary descriptions were generated to assist with establishing stratigraphic correlations across the site. The observations for the soil summary descriptions of borings B-2 and B-4 through B-6 for Transect B were made on 5/20/2013. All of the GEOCON borings along Transect B appear to contain a stacked sequence of Early Holocene-aged to Late a Pleistocene-aged soils.

AMEC BORING SUMMARY DESCRIPTIONS

The core samples from AMEC borings B-5, B-6, and B-7 along transect B were briefly reviewed for soil properties on 6/12/2012. These soil summary descriptions for the AMEC borings are listed in Tables 10.1 through 10.3. The AMEC borings along Transect B all appear to contain a truncated and thin Early Holocene-aged to Latest Pleistocene-aged soil at the ground surface.

CONCLUSIONS

The soils observed across the study area are mainly alfisols that have developed in alluvial environments. All six of the soil profiles across Transects A and B consist of a series of stacked, truncated, and buried argillic soil horizons. The truncated and buried soils with argillic sub surface soil horizons are moderately well to strongly developed. The buried alfisol soils typically have 10 YR colors with a moderate amount of secondary (pedogenic) clay in a series of argillic (Bt) diagnostic subsurface horizons.

The near surface buried soil profiles across the project site area are laterally continuous, and dip gently to the north. Lateral variability in the soils across the site is due to localized scouring, infilling, and stacking of these materials in an alluvial environment. In this sedimentological environment surfaces that have been stable long enough to form a robust soil, can suddenly be buried by a new deposit, or scoured out (truncated) and possibly in-filled with younger material. The amount of erosion that has occurred with each truncated soil under study is unknown. Thus the relative age estimates given in this study are minimum ages.

These soil relative age determinations are consistent with the general geologic and pedogenic observations of soils in southern California. Strongly developed, well horizonated, thick, and oxidized alfisols can be as much as 200 ka in age. Erosion tends to act as a rejuvenating aspect in soil development, by decreasing the strength of the soil development properties consequent age estimates are younger. In that past magnitudes and rates of erosion is difficult to assess the soil relative age estimates are utilized as minimum ages.

The soils observed along Transect A are Holocene to Pleistocene in age. The buried and stacked soils display soil horizons that have strong argillic horizon development. Age estimates range from 58 to 135 ka for the young and thin alluvial stratigraphic section studied along the southern portion of transect A. An older and thick alluvial section along the northern portion of Transect A has relative age estimates that range from 137 – 322 ka in age. The uppermost buried soil that can be correlated across the entire length of Transect A is a well developed and truncated buried argillic soil profile that ranges in relative age from 19 – 57 ka.

The soils observed along Transect B are Pleistocene in age. The buried and stacked soils display soil horizons that also have strong argillic horizon development. Age estimates range from 92 to 191 ka for the young and thin alluvial stratigraphic section studied along the southern portion of transect B. An older and thick alluvial section along the northern portion of Transect B has relative age estimates that range from 165 – 371 ka in age. The uppermost soil that can be correlated across the entire length of Transect B is a near surface, moderately well developed, and truncated buried argillic soil profile that ranges in relative age from 8 – 19 ka. The underlying truncated soil can also be correlated across the entire length of Transect B, which is a well developed, truncated buried argillic soil profile that ranges in relative age from 36 – 60 ka.

LIMITATIONS

The conclusions and recommendations presented herein are the results of an inherently limited scope. Specifically, the scope of services consisted of an assessment of relative age from core samples and did not participate in any drilling activities at the site. The conclusions and recommendations contained in this report are professional opinions derived in accordance with current standards of professional practice. No warranty is expressed or implied.

This report has been prepared for the exclusive use of GEOCON, Inc. and applies only to the Fault Rupture Hazard Study located at The Westfield Century City Mall. In the event that significant changes in the interpretations of this study to be made, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed by John Helms, CEG, and the conclusions and recommendations of this report are verified in writing.

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Table 1.1
Soil Description - Transect A; Boring 1

Depth (Ft)	Horizon	Transect A; B-1 Description
0 - 16.0	Af	Artificial Fill - not described
16 - 20	NR	No Recovery - no sample
20 - 20.7	AB	Very dark grayish brown (10YR 3/2m mixed), loam, organic rich, slightly hard, friable, slightly to moderately sticky, slightly plastic, fine-grained well sorted sand, common fine and few moderately thick humus films on ped faces, clear lower boundary to;
20.7 - 22	Bw / Btj	Dark yellowish brown (10YR 3/4m, mixed), sandy loam, slightly well oxidized, soft to slightly hard, friable, slightly sticky, non- to slightly plastic, medium-grained moderately well sorted sand, few very fine clay films (or stains) on ped faces, gradational lower boundary to;
22 - 25.9	C1 scour	Dark yellowish brown (10YR 4/4m, mixed), loamy sand, crudely stratified, moderately well oxidized, soft, very friable, non- to slightly sticky, non-plastic, coarse-grained poorly sorted sand, common fine gravel, gradational lower boundary to;
25.9 - 27.7	C2 scour	Dark yellowish brown (10YR 4/3m, mixed), loamy sand to sandy loam, massive, slightly oxidized, soft to slightly hard, friable, slightly sticky, non- to slightly plastic, coarse-grained poorly sorted sand, clear lower boundary to;
27.7 - 31.3	2Btb	Dark yellowish brown (10YR 3/4m, mixed), loam to clay loam, massive, moderately well oxidized, hard, friable to firm, moderately sticky, moderately to very plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces, clear lower boundary to;
31.3 - 32.8	2BCb	Dark yellowish brown (10YR 4/3m, mixed), loam, massive, slightly hard, friable, slightly to moderately sticky, slightly plastic, fine-grained well sorted sand, faintly mottled and gleyed, clear lower boundary to;
32.8 - 35.5	3Bt1b	Dark grayish brown (10YR 4/2m, mixed), clay loam, massive, hard to very hard, firm, moderately to very sticky, very plastic, fine-grained well sorted sand, slightly well oxidized, many fine and common moderately thick clay films on ped faces, abrupt lower boundary to;
35.5 - 36.3	3BCb lam	Brown (10YR 4/3m, mixed), sandy loam to loam, faintly laminated, soft to slightly hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, slightly mottled and gleyed, abrupt lower boundary to;
36.3 - 38.4	4Btb	Dark grayish brown (10YR 4/2m, mixed), clay loam, massive, hard, firm, moderately to very sticky, very plastic, fine-grained well sorted sand, moderately well oxidized, many fine and common moderately thick clay films on ped faces, partially mottled and mostly gleyed, abrupt lower boundary to;
38.4 - 40	4Cb1 scour	Dark gray (10YR 4/1m, mixed), sandy loam, stratified, slightly hard, very friable, non- to slightly sticky, non-plastic, medium-grained moderately well sorted sand, strongly gleyed, gradational lower boundary to;
40 - 42.4	4Cb2 scour	Gray (10YR 5/1m, mixed), loamy sand, massive, soft, very friable, non-sticky, non-plastic, coarse-grained poorly sorted sand, strongly gleyed, clear lower boundary to;
42.4 - 45.3	5Btb trun	Dark Grayish brown (10YR 4/2m, mixed), silt loam, massive, slightly hard, friable, moderately sticky, moderately plastic, coarse-grained poorly sorted sand, few to common fine and medium gravel, few to common fine clay films on ped faces, moderately gleyed, clear lower boundary to;
45.3 - 46.2	5Coxb scour	Brown (7.5YR 4/4m, mixed), loamy sand, crudely stratified, well oxidized, soft, very friable, non-sticky, non-plastic, coarse-grained poorly sorted sand, common to many fine gravel, abrupt lower boundary to;
46.2 - 47.5	6BCb ox trun	Dark yellowish brown (10YR 4/4m, mixed), sandy loam, faintly laminated, moderately well oxidized, slightly hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, gradational lower boundary to;

Table 1.1

Depth (Ft)	Horizon	Transect A; B-1 Description (Continued)
47.5 - 48.3	6Coxb scour	Dark yellowish brown (10YR 4/4m, mixed), loamy sand, massive, moderately well oxidized, soft to slightly hard, friable, non- to slightly sticky, non-plastic, coarse-grained poorly sorted sand, abrupt lower boundary to;
48.3 - 50.9	7Btb1 trun	Dark yellowish brown (10YR 4/4m, mixed), loam, massive, moderately well oxidized, slightly hard to hard, friable, slightly to moderately sticky, slightly plastic, medium-grained moderately well sorted sand, many fine and common moderately thick clay films on ped faces, clear lower boundary to;
50.9 - 52.3	7Btb2	Dark yellowish brown (10YR 4/4m, mixed), silty clay loam, finely laminated, moderately well oxidized, hard, firm, moderately sticky, moderately to very plastic, very fine-grained very well sorted sand, common fine and few moderately thick clay films on ped faces, gradational lower boundary to;
52.3 - 54.5	7Btkb3	Brown (7.5YR 4/4m, mixed), clay loam, massive, well oxidized, very hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, many fine and common moderately thick clay films on ped faces, calcium carbonate stage 1+, well disseminated in matrix and common fine nodules, clear lower boundary to;
54.5 - 55	7BC scour	Yellowish brown (10YR 5/4m mixed), loam, massive, moderately well oxidized, hard, friable, slightly to moderately sticky, slightly plastic, fine-grained well sorted sand, common fine clay films on ped faces, partially gleyed clear lower boundary to;
55 - 58.7	8ABb / 8Btb1	Dark brown (10YR 3/3 m, mixed), silty clay loam, massive, organic rich, slightly oxidized, very hard, firm, moderately to very sticky, very plastic, very fine-grained very well sorted sand, many fine and common moderately thick and thick clay films on ped faces, many fine MnO nodules in matrix, gradational lower boundary to;
58.7 - 65.9	8Btb2	Dark yellowish brown (10YR 4/4m, mixed), loam to clay loam, massive, moderately well oxidized, very hard, firm, moderately to very sticky, moderately to very plastic, fine-grained well sorted sand, few to common fine and medium gravel, many fine and common moderately thick and thick clay films on ped faces and coating clasts, partially gleyed, gradational lower boundary to;
65.9 - 69.3	8BCb / 8Btb3	Brown (10YR 4/3m mixed), loam, massive, slightly oxidized, hard, friable, moderately sticky, moderately plastic, fine- to medium-grained moderately well sorted sand, few fine gravel, many fine, common moderately thick and few thick clay films on ped faces and coating clasts, partially gleyed, gradational lower boundary to;
69.3 - 71.5	9ABb / 9Btb1	Dark brown (10YR 3/3 m, mixed), loam to clay loam, massive, slightly oxidized, slight organics, very hard, firm, moderately to very sticky, very plastic, fine-grained well sorted sand, few to common fine and few moderately thick clay films on ped faces, partially gleyed, gradational lower boundary to;
71.5 - 75	9Btb2	Dark yellowish brown (10YR 4/4m, mixed), clay loam, massive, moderately well oxidized, very hard, firm, moderately to very sticky, very plastic, very fine-grained very well sorted sand, common to many fine and moderately thick clay films on ped faces, partially gleyed, clear lower boundary to;
75 - 75.5	9BCb scour	Brown (10YR 4/3 m, mixed), loamy sand to sandy loam, massive, slightly oxidized, slightly hard, friable, non- to slightly sticky, non-plastic, medium- to coarse-grained poorly sorted sand, common fine gravel, undetermined (No recovery) lower boundary to;
75.5 - 80	NR	No Recovery
80 - 82.7	10Btb trun	Dark yellowish brown (10YR 3/4m, mixed), clay loam, massive, moderately well oxidized, very hard, firm, moderately sticky, moderately to very plastic, fine-grained well sorted sand, common to many moderately thick and few thick clay films on ped faces, clear lower boundary to;

Table 1.1

Depth (Ft)	Horizon	Transect A; B-1 Description (Continued)
82.7 - 83.9	10BCoxb scour	Dark yellowish brown (10YR 4/4 m, mixed), loamy sand to sandy loam, crudely stratified, moderately well oxidized, hard, friable, slightly sticky, non- to slightly plastic, coarse-grained poorly sorted sand, few fine gravel, clear lower boundary to;
83.9 - 86	11Btb trun	Dark grayish brown (2.5Y 4/2 m, mixed), silt loam, massive, very hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, common to many thin and moderately thick clay films on ped faces, partially mottled and strongly gleyed, gradational lower boundary to;
86 - 90	11BCb lam	Brown (10YR 4/3 m, mixed), loam, laminated (lams 2 to 3" thick, randomly spaced) slightly oxidized, hard, friable to firm, moderately sticky, slightly to moderately plastic, fine-grained well sorted sand, few fine MnO nodules, partially gleyed, gradational lower boundary to;
90 - 92.2	11Cb scour	Dark grayish brown (10YR 4/2m mixed), sandy loam, massive, slightly oxidized, soft to slightly hard, friable, non- to slightly sticky, non-plastic, medium-grained moderately well sorted sand, well oxidized along base, abrupt lower boundary to;
92.2 - 92.7	12ABb / 12Btb1 trun	Very dark grayish brown (10YR 3/2 m, mixed), loam to silt loam, massive, slight organics, slightly hard to hard, friable to firm, moderately sticky, moderately plastic, fine-grained well sorted sand, many fine and common moderately thick clay films on ped faces, few fine MnO veinlets, clear lower boundary to;
92.7 - 94.5	12Btb2	Dark grayish brown (10YR 4/2 m, mixed), clay loam, faintly laminated, hard, firm, very sticky, very plastic, fine-grained well sorted sand, common thin and few moderately thick clay films on ped faces, strongly mottled and gleyed, gradational lower boundary to;
94.5 - 95.5	12BCb scour	Dark Gray (2.5Y 4/1 m, mixed), loamy sand to sandy loam, massive, slightly hard, friable, non- to slightly sticky, non-plastic, medium-grained poorly sorted sand, few fine gravel, strongly gleyed, abrupt lower boundary to;
95.5 +	Lakewood Fm.	Bedrock. Highly weathered and poorly lithified.

Table 1.2

Soil Development Index Calculation Sheet
Transect A, Boring 1

Unit	Thickness	Color				Texture		Consistence				Clay Films		Horizon	Mean Hor.
	(Feet)	Dry		Moist				Dry		Wet				Values	Values
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Boring 1															
AB	0.7	n.d.	0	10YR 3/2	0	l	0.5	sh	0.40	ss-s, ps	0.42	2fpf, 1mkpf	0.5	0.36	0.25
Bw / Btj	1.3	n.d.	0	10YR 3/4	0.1	sl	0.33	so-sh	0.3	ss, po-ps	0.25	v1vfpf	0.2	0.24	0.31
C1 scour	3.9	n.d.	0	10YR 4/4	0.1	ls	0.16	so	0.2	so-ss, po	0.08		0	0.11	0.42
C2 scour	1.8	n.d.	0	10YR 4/3	0	ls-sl	0.25	so-sh	0.3	ss, po-ps	0.25		0	0.16	0.29
2Btb	3.6	n.d.	0	10YR 3/4	0.1	l-cl	0.58	h	0.6	s, p-vp	0.75	2fpf, 1mkpf	0.5	0.51	1.82
2BCb	1.5	n.d.	0	10YR 4/3	0	l	0.5	sh	0.4	ss-s, ps	0.42		0	0.26	0.40
3Bt1b	2.7	n.d.	0	10YR 4/2	0	cl	0.67	h - vh	0.7	s-vs, vp	0.92	3fpf, 2mkpf	0.6	0.58	1.56
3BCb lam	0.7	n.d.	0	10YR 4/3	0	sl-l	0.42	sh	0.4	ss, po-ps	0.25		0	0.21	0.15
4Btb	2.1	n.d.	0	10YR 4/2	0	cl	0.67	h	0.6	s-vs, vp	0.92	3fpf, 2mkpf	0.6	0.56	1.17
4Cb1 scour	1.6	n.d.	0	10YR 4/1	0	sl	0.33	sh	0.40	so-ss, po	0.08		0	0.16	0.26
4Cb2 scour	2.4	n.d.	0	10YR 5/1	0	ls	0.16	so	0.20	so, po	0.00		0	0.07	0.17
5Btb trun	2.9	n.d.	0	10YR 4/2	0	sil	0.67	sh	0.40	s, p	0.67	1-2fpf	0.3	0.41	1.18
5Coxb scour	0.9	n.d.	0	7.5YR 4/4	0.2	ls	0.16	so	0.20	so, po	0.00		0	0.11	0.10
6BCb ox trun	1.3	n.d.	0	10YR 4/4	0.1	sl	0.33	sh	0.40	ss, po-ps	0.25		0	0.22	0.28
6Coxb scour	0.8	n.d.	0	10YR 4/4	0.1	ls	0.16	so - sh	0.30	so-ss, po	0.08		0	0.13	0.10
7Btb1 trun	2.6	n.d.	0	10YR 4/4	0.1	l	0.5	sh - h	0.50	ss-s, ps	0.42	3fpf, 2mkpf	0.6	0.42	1.10
7Btb2	1.4	n.d.	0	10YR 4/4	0.1	sicl	0.67	h	0.60	s, p-vp	0.75	2fpf, 1mkpf	0.5	0.52	0.73
7Btkb3	2.2	n.d.	0	7.5YR 4/4	0.2	l-cl	0.58	vh	0.80	vs, vp	1.00	3fpf, 2mkpf	0.6	0.64	1.40
7BC scour	0.5	n.d.	0	10YR 5/4	0.1	l	0.5	h	0.60	ss-s, ps	0.42	2fpf	0.33	0.39	0.20
8ABb / 8Btb1	3.7	n.d.	0	10YR 3/3	0	l-cl	0.58	vh	0.80	s-vs, vp	0.92	2kpf	0.83	0.63	2.32
8Btb2	7.2	n.d.	0	10YR 4/4	0.1	cl	0.67	vh	0.80	s-vs, p-vp	0.83	2kpf	0.83	0.65	4.65
8BCb / 8Btb3	3.4	n.d.	0	10YR 4/3	0	l	0.5	h	0.60	s, p	0.67	1kpf	0.8	0.51	1.75
9ABb / 9Btb1	2.2	n.d.	0	10YR 3/3	0	l-cl	0.58	vh	0.80	s-vs, vp	0.92	1-2fpf, 1mkpf	0.52	0.56	1.24
9Btb2	3.5	n.d.	0	10YR 4/4	0.1	cl	0.67	vh	0.8	s-vs, vp	0.92	2fpf, 2mkpf	0.57	0.61	2.14
9BCb scour	0.5	n.d.	0	10YR 4/3	0	ls-sl	0.25	sh	0.4	so-ss, po	0.08		0	0.15	0.07
10Btb trun	2.7	n.d.	0	10YR 3/4	0.1	cl	0.67	vh	0.8	s, p-vp	0.92	2-3mkpf, 1kpf	0.63	0.62	1.68
10BCoxb scour	1.2	n.d.	0	10YR 4/4	0.1	ls-sl	0.25	h	0.6	ss, po-ps	0.25		0	0.24	0.29
11Btb trun	2.1	n.d.	0	2.5Y 4/2	0	sil	0.67	vh	0.8	vs, vp	1	2-3fpf, 2-3mkpf	0.38	0.57	1.20
11BCb lam	4.0	n.d.	0	10YR 4/3	0	l	0.5	h	0.6	s, ps-p	0.58		0	0.34	1.34
11Cb scour	2.2	n.d.	0	10YR 4/2	0	sl	0.33	so - sh	0.3	so-ss, po	0.08		0	0.14	0.31
12ABb / 12Btb1 trun	0.5	n.d.	0	10YR 3/2	0	l-sil	0.58	sh - h	0.5	s, p	0.67	3fpf, 2mkpf	0.6	0.47	0.24
12Btb2	1.8	n.d.	0	10YR 4/2	0	cl	0.67	h	0.6	vs, vp	1	2fpf, 1mkpf	0.5	0.55	1.00
12BCb scour	1.0	n.d.	0	2.5Y 4/1	0	ls-sl	0.25	sh	0.4	so-ss, po	0.08		0	0.15	0.15

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.36**	**1.27**	**1.16**	**0.2**	**0.70**	**4 - 8**	**4 - 8**
Buried Soil 1	**0.51**	**2.22**	**3.04**	**0.1**	**0.50**	**15 - 30**	**19 - 38**
Buried Soil 2	**0.58**	**1.71**	**3.52**	**0**	**0.60**	**15 - 30**	**34 - 68**
Buried Soil 3	**0.56**	**1.60**	**1.84**	**0**	**0.60**	**8 - 15**	**42 - 83**
Buried Soil 4	**0.41**	**1.28**	**2.36**	**0.2**	**0.30**	**8 - 15**	**50 - 98**
Buried Soil 5	**0.22**	**0.38**	**1.28**	**0.2**	**0.00**	**1 - 4**	**51 - 102**
Buried Soil 6	**0.64**	**3.43**	**3.58**	**0.5**	**2.03**	**15 - 30**	**66 - 132**
Buried Soil 7	**0.65**	**8.72**	**4.27**	**0.1**	**2.46**	**30 - 70**	**96 - 202**
Buried Soil 8	**0.61**	**3.46**	**3.90**	**0.1**	**1.09**	**15 - 30**	**111 - 232**
Buried Soil 9	**0.62**	**1.97**	**3.54**	**0.2**	**0.63**	**15 - 30**	**126 - 262**
Buried Soil 10	**0.57**	**2.85**	**2.41**	**0**	**0.38**	**15 - 30**	**141 - 292**
Buried Soil 11	**0.55**	**1.38**	**2.92**	**0**	**1.10**	**15 - 30**	**156 - 322**

Table 2.1

Soil Description - Transect A; Boring 4

Depth (Ft)	Horizon	Transect A; B-4 Description
0 - 9.5	Af	Artificial Fill
9.5 -15	AB/Bt	Dark brown, to very dark grayish brown (10-7.5YR 3/2d, 2/1m mixed), loam to clay loam, organic rich, very hard, firm, moderately to very sticky, very plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces, gradational lower boundary to;
15 - 15.5	BC ox	Dark yellowish brown (10YR 4/4d, 3/3m mixed), loam, slightly oxidized, hard, friable, moderately sticky, slightly to moderately plastic, fine-grained well sorted sand, few fine clay films on ped faces, clear lower boundary to;
15.5 - 16.1	C scour	Yellowish brown (10YR 5/4d, 4/3m mixed), sandy loam, soft, friable, slightly sticky, non- to slightly plastic, coarse-grained poorly sorted sand, common fine slate gravel, abrupt lower boundary to;
16.1 - 21	2Bwb/2Btjb	Yellowish brown (10YR 4/4d, 4/3m mixed), loam, slightly hard to hard, friable, slightly sticky, slightly plastic, fine-grained well sorted sand, few fine clay films on ped faces, gradational lower boundary to;
21 - 22.1	2BCb	Brown (10YR 5/3d, 3/3m mixed), loamy sand, soft, very friable, non- to slightly sticky, non- plastic, fine-grained well sorted sand, clear lower boundary to;
22.1 - 25.75	2Cb scour	Grayish brown (10YR 5/2d, 3/1m mixed), gravelly sandy loam, loose to soft, very friable, non-sticky, non-plastic, coarse-grained poorly sorted sand, common to many slate gravel, abrupt lower boundary to;
25.75 - 26.25	3Bwb	Dark yellowish brown (10YR 4/4d, 3/2m mixed), sandy loam, slightly hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, common fine slate gravel, very few fine clay films on ped faces and coating gravel, abrupt lower boundary to;
26.25 - 28	3C scour	Brown (10YR 5/3d, 3/2m mixed), loamy sand, loose to soft, very friable, non-sticky, non-plastic, coarse-grained poorly sorted sand, common to many fine slate gravel, clear lower boundary to;
28 - 30.2	4ABb/4Btb	Yellowish brown (10YR 5/4d, 3/3m mixed), loam, slightly oxidized, slight organics, slightly hard, friable, slightly to moderately sticky, slightly plastic, fine-grained well sorted sand, few fine clay films on ped faces and coating clasts, clear lower boundary to;
30.2 - 33.5	5Btb1 trun	Brown (7.5YR 4/4d, 3/2m mixed), sandy clay loam to clay loam, moderately well oxidized, slight organics, hard to very hard, friable to firm, very sticky, moderately to very plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces and coating clasts, gradational lower boundary to;

Table 2.1

Depth (Ft)	Horizon	Transect A; B-4 Description (Continued)
33.5 - 36.25	5Btb2	Brown (7.5YR 5/4d, 3/3m mixed), sandy clay loam to loam, moderately well oxidized, hard, friable, moderately sticky, slightly to moderately plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces, gradational lower boundary to;
36.25 - 44.5	5BCb lam	Yellowish brown (10YR 5/4d, 3/3m mixed), loamy sand to sandy loam with localized clay loam zones, slightly oxidized, soft to slightly hard, friable, slightly sticky, non- to slightly plastic, fine to medium-grained moderately well sorted sand, varve like stratification, clear lower boundary to;
44.5 - 45	6Btb trun	Brown (7.5YR 5/4d, 3/2m mixed), gravelly loam, moderately well oxidized, common MnO coatings, hard, friable, slightly to moderately sticky, slightly plastic, coarse-grained poorly sorted sand, common well rounded gravel, many fine, common moderately thick, and few thick clay films on ped faces and common moderately thick coating gravel, clear lower boundary to;
45 - 46.5	6BCb ox	Yellowish brown to brown (10-7.5YR 5/4d, 3/3m mixed), sandy loam, slightly to moderately well oxidized, slightly hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, common fine clay films on ped faces, gradational lower boundary to;
46.5 - 54.5	7Btb1 trun	Strong brown (7.5YR 4/6d, 3/3m mixed), clay loam, well oxidized, very hard, firm, very sticky, very plastic, fine-grained well sorted sand, many moderately thick and common thick clay films on ped faces, gradational lower boundary to;
54.5 - 60.5	7Btb2	Yellowish brown (10YR 5/4d, 3/2m mixed), loam to clay loam, slightly oxidized, faint primary stratigraphy preserved, hard to very hard, firm, very sticky, moderately to very plastic, coarse-grained poorly sorted sand, common gravel, many fine and common moderately thick clay films on ped faces, abrupt lower boundary to;
60.5 - 62	7Cb scour	Light yellowish brown (10YR 6/4d, 4/2m mixed), loamy sand, soft, very friable, non- to slightly sticky, non- plastic, coarse-grained poorly sorted sand, common fine slate gravel, abrupt lower boundary to;
62 - 65.5	8Btb trun	Yellowish brown (10YR 5/4d, 3/3m mixed), loam to clay loam, slightly oxidized, faint varve like stratigraphy preserved, hard to very hard, firm, very sticky, moderately to very plastic, fine-grained well sorted sand, many fine and common moderately thick clay films on ped faces, clear lower boundary to;
65.5 - 66	8Cb scour	Brown (10YR 5/3d, 4/2m mixed), sandy loam, soft, very friable, slightly sticky, non-plastic, fine-grained well sorted sand, massive, abrupt lower boundary to;

Table 2.1

Depth (Ft)	Horizon	Transect A; B-4 Description (Continued)
66 - 72.5	9BCb lam /9Cb	Stacked sequence of Dark grayish brown (10YR 5/2d, 4/1m mixed), loam - clay loams, strongly mottled with varve like stratigraphy preserved, hard, firm, very sticky, moderately to very plastic, fine-grained well sorted sand, common thin and moderately thick clay films on ped faces, with abrupt lower boundaries to - Interbedded scours, Brown to yellowish brown (10YR 5/3-4d, 4/2m), sandy loam to loamy sand, soft to loose, very friable, non-sticky, non-plastic, coarse-grained poorly sorted sand, massive, clear lower boundary to;
72.5 - 78.25	10Btb lam	Brown (7.5YR 5/4d, 3/3m mixed), loam - clay loams, strongly mottled with varve like stratigraphy preserved, moderately well oxidized, hard, firm, very sticky, moderately to very plastic, fine-grained well sorted sand, common thin and moderately thick clay films on ped faces, abrupt lower boundary to;
78.25 - 85	10Cb scour	Light yellowish brown (10YR 6/4d, 4/2m mixed), loamy sand, soft to loose, very friable, non- to slightly sticky, non-plastic, medium-grained moderately well sorted sand, massive to crudely bedded, abrupt lower boundary to;
85+	Lakewood Fm.	Bedrock. Highly weathered bedrock.

Table 2.2

Soil Development Index Calculation Sheet
Transect A; Boring 4

Unit	Thickness	Color				Texture		Consistence				Clay Films		Horizon	Mean Hor.
	(Feet)	Dry		Moist				Dry		Wet				Values	Values
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Boring 4															
AB/Bt	5.5	10-7.5YR 3/2	0.15	10-7.5YR 2/1	0.05	l - cl	0.58	vh	0.80	s-vs, vp	0.92	2fpf, 1mkpf	0.5	0.50	2.75
BC ox	0.5	10YR 4/4	0.3	10YR 3/3	0	l	0.5	h	0.6	s, ps-p	0.58	1fpf	0.27	0.38	0.19
C scour	0.4	10YR 5/4	0.3	10YR 4/3	0	sl	0.33	so	0.2	ss, po-ps	0.25		0	0.18	0.07
2Bwb/2Btjb	4.9	10YR 4/4	0.3	10YR 4/3	0	l	0.5	sh-h	0.5	ss, ps	0.33	1fpf	0.27	0.32	1.55
2BCb	1.1	10YR 5/3	0.2	10YR 3/3	0	sl	0.33	so	0.2	so, po-ps	0.08		0	0.14	0.15
2Cb scour	3.65	10YR 5/2	0.1	10YR 2/1	0	ls	0.16	lo-so	0.1	so, po	0.00		0	0.06	0.22
3Bwb	0.5	10YR 4/4	0.3	10YR 3/2	0	sl	0.33	sh	0.4	ss, po-ps	0.25	v1fpf, v1fcl	0.3	0.26	0.13
3C scour	1.75	10YR 5/3	0.2	10YR 3/2	0	ls	0.16	lo-so	0.1	so, po	0		0	0.08	0.13
4ABb/4Btb	2.2	10YR 5/4	0.3	10YR 3/3	0	l	0.5	sh	0.4	ss-s, ps	0.42	1fpf, 1fcl	0.38	0.33	0.73
5Btb1 trun	3.3	7.5YR 4/4	0.4	7.5YR 3/2	0.1	scl-cl	0.67	h-vh	0.70	vs, p-vp	0.92	2fpf, 1mkpf, 2mkcl	0.67	0.58	1.90
5Btb2	2.75	7.5YR 5/4	0.4	7.5YR 3/3	0	scl-l	0.58	h	0.60	s, ps-p	0.58	2fpf, 1mkpf	0.5	0.44	1.22
5BCb lam	8.25	10YR 5/4	0.3	10YR 3/3	0	ls-sl	0.25	so-sh	0.30	ss-s, ps	0.42		0	0.21	1.75
6Btb trun	0.5	7.5YR 5/4	0.4	7.5YR 3/2	0.1	l	0.5	h	0.60	ss-s, ps	0.42	3fpf, 2mkpf, 1kpf, 2mkcl	0.88	0.48	0.24
6BCb ox	1.5	10-7.5YR 5/4	0.35	10-7.5YR 3/3	0.05	sl	0.33	sh	0.40	ss, po-ps	0.25		0	0.23	0.35
7Btb1 trun	8	7.5YR 4/6	0.6	7.5YR 3/3	0.1	cl	0.67	vh	0.80	vs, vp	1.00	3mkpf, 2kpf	0.6	0.63	5.03
7Btb2	6	10YR 5/4	0.3	10YR 3/2	0	l-cl	0.58	h-vh	0.70	vs, p-vp	0.92	3fpf, 2mkpf	0.6	0.52	3.10
7Cb scour	1.5	10YR 6/4	0.3	10YR 4/2	0	ls	0.16	so	0.20	so-ss, po	0.08		0	0.12	0.19
8Btb trun	3.5	10YR 5/4	0.3	10YR 3/3	0	l-cl	0.58	h-vh	0.70	vs, p-vp	0.92	3fpf, 2mkpf	0.6	0.52	1.81
8Cb scour	0.5	10YR 5/3	0.2	10YR 4/2	0	sl	0.33	so	0.20	ss, po	0.17		0	0.15	0.08
9BCb lam /9Cb	6.5	10YR 5/3	0.2	10YR 4/2	0	sl-l	0.42	sh	0.40	s, p	0.67	2fpf, 1mkpf	0.5	0.37	2.37
10Btb lam	5.75	7.5YR 5/4	0.4	7.5YR 3/3	0.1	l-cl	0.58	h	0.60	vs, p-vp	0.92	2fpf, 1mkpf	0.5	0.52	2.97
10Cb scour	6.75	10YR 6/4	0.3	10YR 4/2	0	ls	0.16	lo-so	0.10	so-ss, po	0.08		0	0.11	0.72

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.50**	**3.01**	**3.29**	**0.75**	**0.77**	**8 - 15**	**8 - 15**
Buried Soil 1	**0.32**	**1.92**	**1.39**	**0.6**	**0.27**	**4 - 8**	**12 - 23**
Buried Soil 2	**0.26**	**0.27**	**0.83**	**0.5**	**0.30**	**1 - 4**	**13 - 27**
Buried Soil 3	**0.33**	**0.73**	**2.33**	**0.3**	**0.38**	**15 - 30**	**28 - 57**
Buried Soil 4	**0.58**	**4.87**	**2.38**	**1.1**	**0.72**	**30 - 70**	**58 - 127**
Buried Soil 5	**0.48**	**0.59**	**2.05**	**0.75**	**0.88**	**15 - 30**	**73 - 157**
Buried Soil 6	**0.63**	**8.31**	**3.75**	**1.2**	**1.20**	**30 - 70**	**103 - 227**
Buried Soil 7	**0.52**	**1.88**	**3.30**	**0.5**	**0.60**	**15 - 30**	**118 - 257**
Buried Soil 8	**0.37**	**2.37**	**2.56**	**0.2**	**0.50**	**4 - 8**	**122 - 265**
Buried Soil 9	**0.52**	**3.69**	**2.07**	**0.7**	**0.50**	**15 - 30**	**137 - 295**

Table 3.1

Soil Description - Transect A; Boring 5

Depth (Ft)	Horizon	Transect A; B-5 Description
0 - 9.45	Af	Artificial Fill
9.45 - 11.4	AB/Bt	Dark brown (7.5YR 3/4d, 2/3m mixed), clay loam, moderately well oxidized, organic rich, hard to very hard, firm, very sticky, very plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces and coating clasts, few fine gravel, undetermined (no recovery) lower boundary to;
20 - 21.8	BC ox	Yellowish brown (10YR 5/4d, 3/3m mixed), loam to sandy loam, slightly oxidized, slightly hard to hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, few fine clay films on ped faces, abrupt lower boundary to;
21.8 - 25.6	C scour	Brown (10YR 5/3d, 4/2m mixed), loamy sand with gravel, loose to soft, very friable, non- to slightly sticky, non-plastic, coarse-grained poorly sorted sand, common fine slate gravel, clay stains on gravel, abrupt lower boundary to;
25.6 - 26.3	2Bwb	Yellowish brown (10YR 5/4d, 4/3m mixed), sandy loam, slightly oxidized, slightly hard, friable, slightly sticky, non- to slightly plastic, coarse-grained poorly sorted sand, abrupt lower boundary to;
26.3 - 28.3	2Cb scour	Pale brown (10YR 6/3d, 4/2m mixed), loamy sand, loose - soft, very friable, non- to slightly sticky, non-plastic, coarse-grained poorly sorted sand, common fine slate gravel, clear lower boundary to;
28.3 - 31.1	3ABb/Btb	Yellowish brown (10YR 5/4d, 4/3m mixed), loam, slight organics, slightly oxidized, slightly hard, friable, moderately sticky, slightly to moderately plastic, fine-grained well sorted sand, few to common fine clay films on ped faces, clear lower boundary to;
31.1 - 33.4	4Btb1 trun	Brown (7.5YR 4/4d, 3/3m mixed), clay loam, slightly oxidized, hard to very hard, firm, very sticky, very plastic, fine-grained well sorted sand, many fine and common moderately thick clay films on ped faces and coating clasts, few fine gravel, clear lower boundary to;
33.4 - 36.1	4Btb2	Brown (7.5YR 4/4d, 3/3m mixed), clay loam, slightly to moderately well oxidized, hard, firm, very sticky, very plastic, medium-grained moderately well sorted sand, common thin and moderately thick clay films on ped faces and coating clasts, few fine gravel, abrupt lower boundary to;
36.1 - 36.95	4Cb scour	Brown (10YR 4/3d, 3/2m mixed), gravelly loam, hard, friable to firm, moderately sticky, slightly to moderately plastic, coarse-grained poorly sorted sand, common fine gravel, common MnO staining on gravel, abrupt lower boundary to;

Table 3.1

Depth (Ft)	Horizon	Transect A; B-5 Description (Continued)
36.95 - 37.85	5Bwb/BCb lam	Brownish yellow (10YR 6/6d, 4/4m mixed), loam, moderately well to well oxidized, slightly hard to hard, friable, moderately sticky, slightly to moderately plastic, medium-grained moderately well sorted sand, strongly mottled, clear lower boundary to;
37.85 - 50	5Cb scour	Light yellowish brown (2.5Y 6/3d, 5/2m mixed), sandy loam to loam, slightly hard, friable, slightly sticky, slightly plastic, fine-grained well sorted sand, massive to crudely bedded, mottled and strongly gleyed, abrupt lower boundary to;
50+	Lakewood Fm.	Bedrock. Highly weathered and poorly lithified sandstone.

Table 3.2

Soil Development Index Calculation Sheet
Transect A; Boring 5

Unit	Thickness (Feet)	Color				Texture		Consistence				Clay Films		Horizon Values	Mean Hor. Values
		Dry		Moist				Dry		Wet					
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Boring 5															
AB/Bt	1.95	7.5YR 3/4	0.4	7.5YR 2/3	0.1	cl	0.67	h - vh	0.70	vs, vp	1.00	2fpf, 1mkpf	0.5	0.56	1.10
BC ox	1.8	10YR 5/4	0.3	10YR 3/3	0	l -sl	0.42	sh - h	0.5	ss, po-ps	0.25	1fpf	0.27	0.29	0.52
C scour	3.8	10YR 5/3	0.2	10YR 4/2	0	ls	0.16	lo - so	0.1	so-ss, po	0.08	v1vncl	0.2	0.12	0.47
2Bwb	0.7	10YR 5/4	0.3	10YR 4/3	0	sl	0.33	sh	0.4	ss, po-ps	0.25		0	0.21	0.15
2Cb scour	2	10YR 6/3	0.2	10YR 4/2	0	ls	0.16	lo - so	0.1	so-ss, po	0.08		0	0.09	0.18
3ABb/Btb	2.8	10YR 5/4	0.3	10YR 4/3	0	l	0.5	sh	0.4	s, ps-p	0.58	1-2fpf	0.3	0.35	0.97
4Btb1 trun	2.3	7.5YR 4/4	0.4	7.5YR 4/3	0.1	cl	0.67	h - vh	0.70	vs, vp	1.00	3fpf, 2mkpf, 2mkcl	0.77	0.61	1.40
4Btb2	2.7	7.5YR 4/4	0.4	7.5YR 3/3	0.1	cl	0.67	h	0.6	vs, vp	1.00	2fpf, 2mkpf, 2mkcl	0.67	0.57	1.55
4Cb scour	0.85	10YR 4/3	0.2	10YR 3/2	0	l	0.5	h	0.6	s, ps-p	0.58		0	0.31	0.27
5Bwb/BCb lam	0.9	10YR 6/6	0.5	10YR 4/4	0.1	l	0.5	sh - h	0.5	s, ps-p	0.58		0	0.36	0.33
5Cb scour	12.2	2.5Y 6/3	0.1	2.5Y 5/2	0	sl - l	0.42	sh	0.4	ss, ps	0.33		0	0.21	2.54

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.56**	**2.09**	**1.93**	**0.9**	**0.97**	**8 - 15**	**8 - 15**
Buried Soil 1	**0.21**	**0.33**	**0.85**	**0.5**	**0.00**	**1 - 4**	**9 - 19**
Buried Soil 2	**0.35**	**0.97**	**2.43**	**0.3**	**0.30**	**15 - 30**	**24 - 49**
Buried Soil 3	**0.61**	**3.21**	**3.84**	**1**	**1.44**	**30 - 70**	**54 - 119**
Buried Soil 4	**0.36**	**2.87**	**1.53**	**0.6**	**0.00**	**4 - 8**	**58 - 127**

Table 4.1

Soil Description - Transect A; Boring 7

Depth (Ft)	Horizon	Transect A; B-7 Description
0 - 15	Af	Artificial Fill
15 - 17.5	AB/Bt	Dark brown(7.5YR 3/4d, 3/2m mixed), loam, organic rich, hard to very hard, friable, moderately sticky, slightly plastic, fine-grained well sorted sand, few fine clay films on ped faces, gradational lower boundary to;
17.5 - 21	BC ox	Yellowish brown (10YR 5/4d, 3/3m mixed), loam to sandy loam, slightly oxidized, hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, few very fine clay films on ped faces, gradational lower boundary to;
21 - 21.5	C scour	Yellowish brown (10YR 5/4d, 3/3m mixed), loamy sand, slightly oxidized, slightly hard, friable, slightly sticky, non- to slightly plastic, coarse-grained poorly sorted sand, common fine slate gravel, clay stains on gravel, abrupt lower boundary to;
21.5 - 22.5	2Bwb	Yellowish brown (10YR 5/4d, 4/3m mixed), sandy loam, slightly oxidized, soft to slightly hard, very friable, non- to slightly sticky, non-plastic, medium-grained moderately well sorted sand, abrupt lower boundary to;
22.5 - 22.75	2Cb scour	Pale brown (10YR 6/3d, 4/2m mixed), loamy sand, loose - single grained, very friable, non-sticky, non-plastic, coarse-grained poorly sorted sand, abrupt lower boundary to;
22.75 - 29.5	3Btjb/3BCb lam stacked	Yellowish brown (10YR 5/4d, 4/3m mixed), loam, slightly oxidized, slightly hard, friable, slightly to moderately sticky, slightly plastic, fine-grained well sorted sand, few very fine and fine clay films on ped faces, undetermined lower boundary (no recovery) to;
30 - 32.5	4ABb/Btb	Dark yellowish brown (10YR 4/4d, 3/3m mixed), loam, slightly oxidized, slight organics, slightly hard, friable, moderately sticky, slightly to moderately plastic, fine-grained well sorted sand, few to common fine clay films on ped faces, clear lower boundary to;
32.5 - 35.5	5Btb1 trun	Brown (7.5YR 4/4d, 2.5/2m mixed), loam to clay loam, slightly to moderately well oxidized, hard to very hard, friable to firm, very sticky, moderately to very plastic, fine-grained well sorted sand, many thin and common moderately thick clay films on ped faces and coating clasts, few fine gravel, gradational lower boundary to;
35.5 - 46	6Bwb/6BCb lam stacked	Stacked sequence of Brown (10YR 5/3d, 4/2m mixed), loams, strongly mottled with varve like stratigraphy preserved, slightly hard, friable to firm, moderately sticky, slightly to moderately plastic, fine-grained well sorted sand, abrupt lower boundaries to - Interbedded scours, Yellowish brown (10YR 5/4d, 4/3m mixed), sandy loam to loamy sand, soft to slightly hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, massive, abrupt lower boundary to;

Table 4.1

Depth (Ft)	Horizon	Transect A; B-7 Description (Continued)
46 - 47.25	6Cb scour	Brown (10YR 5/3d, 4/2m mixed), sandy loam, soft to loose, very friable, slightly sticky, non-plastic, coarse-grained poorly sorted sand, massive to crudely bedded, abrupt lower boundary to;
47.25+	Lakewood Fm.	Bedrock. Highly weathered and poorly lithified sandstone.

Table 4.2

Soil Development Index Calculation Sheet
Transect A; Boring 7

Unit	Thickness (Feet)	Color Dry		Color Moist		Texture		Consistence Dry		Consistence Wet		Clay Films		Horizon Values	Mean Hor. Values
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Boring 7															
AB/Bt	2.5	7.5YR 3/4	0.4	7.5YR 3/2	0.1	l	0.5	vh	0.80	s, ps	0.50	1fpf	0.27	0.43	1.07
BC ox	3.5	10YR 5/4	0.3	10YR 3/3	0	l -sl	0.42	h	0.6	ss, po-ps	0.25	v1fpf	0.23	0.30	1.05
C scour	0.5	10YR 5/4	0.3	10YR 3/3	0	ls	0.16	sh	0.4	ss, po-ps	0.25	v1vncl	0.2	0.22	0.11
2Bwb	1	10YR 5/4	0.3	10YR 4/3	0	sl	0.33	so - sh	0.3	so-ss, po	0.08		0	0.17	0.17
2Cb scour	0.25	10YR 6/3	0.2	10YR 4/2	0	ls	0.16	lo	0	so, po	0.00		0	0.06	0.02
3Btjb/3BCb lam stacked	6.75	10YR 5/4	0.3	10YR 4/3	0	l	0.5	sh	0.4	ss-s, ps	0.42	1vfpf, 1fpf	0.38	0.33	2.25
4ABb/Btb	2.5	10YR 4/4	0.3	10YR 3/3	0	l	0.5	sh	0.4	s, ps-p	0.58	1-2fpf	0.3	0.35	0.87
5Btb1 trun	3	7.5YR 4/4	0.4	7.5YR 2.5/2	0.1	l - cl	0.58	h-vh	0.7	vs, p-vp	0.91	3fpf, 2mkpf, 2mkcl	0.62	0.55	1.66
6Bwb/6BCb lam stacked	10.5	10YR 5/3	0.2	10YR 4/2	0	l - sl	0.42	so - sh	0.3	ss-s, ps	0.42		0	0.22	2.35
6Cb scour	1.25	10YR 5/3	0.2	10YR 4/2	0	sl	0.33	lo - sl	0.10	ss, po	0.17		0	0.13	0.17

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.43**	**2.23**	**2.40**	**1**	**0.70**	**8 - 15**	**8 - 15**
Buried Soil 1	**0.17**	**0.18**	**1.03**	**0.5**	**0.00**	**1 - 4**	**9 - 19**
Buried Soil 2	**0.33**	**2.25**	**2.33**	**0.3**	**0.38**	**4 - 8**	**13 - 27**
Buried Soil 3	**0.35**	**0.87**	**2.43**	**0.3**	**0.30**	**15 - 30**	**28 - 57**
Buried Soil 4	**0.55**	**1.66**	**3.86**	**0.4**	**0.62**	**30 - 70**	**58 - 127**
Buried Soil 5	**0.22**	**2.51**	**1.50**	**0.4**	**0.00**	**4 - 8**	**62 - 135**

Table 5.1
Transect A - Boring 2

Depth (Ft)	Horizon	Summary Description of Transect A; Boring 2
0 - 16.6	Af	Artificial Fill
16.6 - 20.5	Bw / Btj	weak argillic, truncated
20.5 - 23.5	BC	massive, weak
23.5 - 24	C	massive scour
24 - 25	--	No Recovery
25 - 26.3	2ABb/ 2Btb1	moderate argillic, moderately oxidized
26.3 - 30	--	No Recovery
30 - 34.5	3Btb1	strong argillic, plugged with clay, truncated
34.5 - 37	3Btb2	strong argillic, plugged with clay
37 - 47.5	3BCb	crudely stratified (stacked), mottled
47.5 - 56.75	4Btb1	strong argillic with gravel, plugged with clay, well oxidized
56.75 - 58	4Btb2	moderate argillic, sandy, moderately oxidized
58 - 59	4Btb3	moderate argillic, crudely stratified (stacked), mottled
59 - 61	4BCb	massive, sandy, slightly oxidized
61 - 63.5	5Btb1	strong argillic, plugged with clay, slightly oxidized, trun.
63.5 - 65	5Btb2	strong argillic with gravel, slightly oxidized
65 - 69	5Btb3	strong argillic, mottled
69 - 71.8	5Btb4	strong argillic with gravel, mottled
71.8 - 77	5BCb / 5Cb scour	massive scour
77 - 79.25	6Btb	strong argillic, slightly oxidized
79.25 - 80.5	6BCb1	massive, sandy, gleyed
80.5 - 94	6BCb2 / 6Cb1	crudely stratified (stacked)
94 - 105	6Cb2 scour	massive scour
105+	Lakewood Formation	Poorly lithified bedrock.

Table 5.1
Transect A - Boring 2

Depth (Ft)	Horizon	Summary Description of Transect A; Boring 2
0 - 16.6	Af	Artificial Fill
16.6 - 20.5	Bw / Btj	weak argillic, truncated
20.5 - 23.5	BC	massive, weak
23.5 - 24	C	massive scour
24 - 25	--	No Recovery
25 - 26.3	2ABb/ 2Btb1	moderate argillic, moderately oxidized
26.3 - 30	--	No Recovery
30 - 34.5	3Btb1	strong argillic, plugged with clay, truncated
34.5 - 37	3Btb2	strong argillic, plugged with clay
37 - 47.5	3BCb	crudely stratified (stacked), mottled
47.5 - 56.75	4Btb1	strong argillic with gravel, plugged with clay, well oxidized
56.75 - 58	4Btb2	moderate argillic, sandy, moderately oxidized
58 - 59	4Btb3	moderate argillic, crudely stratified (stacked), mottled
59 - 61	4BCb	massive, sandy, slightly oxidized
61 - 63.5	5Btb1	strong argillic, plugged with clay, slightly oxidized, trun.
63.5 - 65	5Btb2	strong argillic with gravel, slightly oxidized
65 - 69	5Btb3	strong argillic, mottled
69 - 71.8	5Btb4	strong argillic with gravel, mottled
71.8 - 77	5BCb / 5Cb scour	massive scour
77 - 79.25	6Btb	strong argillic, slightly oxidized
79.25 - 80.5	6BCb1	massive, sandy, gleyed
80.5 - 94	6BCb2 / 6Cb1	crudely stratified (stacked)
94 - 105	6Cb2 scour	massive scour
105+	Lakewood Formation	Poorly lithified bedrock.

Table 5.2
Transect A - Boring 3

Depth (Ft)	Horizon	Summary Description of Transect A; Boring 3
0 - 12.3	Af	Artificial Fill
12.3 - 15.2	AB / Bt	moderate argillic, organic rich, truncated
15.2 - 15.75	C scour	massive scour
15.75 - 19.25	2Btjb / 2BCb	massive, weak
19.25 - 20	--	No Recovery
20 - 21	2Cb scour	massive scour
21 - 26.5	3Bwb / 3Btjb	massive, weak
26.5 - 27	3Cb scour	massive scour
27 - 30.5	4ABb / 4Btb1	strong argillic, plugged with clay, organic rich, truncated
30.5 - 33.75	4Btb2	strong argillic, plugged with clay
33.75 - 36.5	4Btb3	strong argillic, plugged with clay
36.5 - 42.75	4BCb	crudely stratified (stacked), laminated sands
42.75 - 48.5	4Cb	massive scour
48.5 - 50.25	5Btb1	strong argillic, plugged with clay, truncated
50.25 - 52.25	5Btb2	strong argillic, plugged with clay
52.25 - 59	5Btb3	strong argillic, plugged with clay
59 - 65	5Btb4	strong argillic, plugged with clay
65 - 66	5Cb scour	massive weak scour
66 - 70 +	6Btb	strong argillic, plugged with clay

Table 5.3
Transect A - Boring 9

Depth (Ft)	Horizon	Summary Description of Transect A; Boring 9
0 - 15.0	Af	Artificial Fill
15 - 17.3	AB / Bt1	strong argillic, plugged with clay, organic rich, truncated
17.3 - 18	Bt2	strong argillic, plugged with clay
18 - 20	--	No Recovery
20 - 20.7	BC	massive, weak
20.7 - 21.9	C1	crudely stratified, gravelly
21.9 - 29.2	C2	massive scour, sandy
29.2 - 35.5	2Btb1	strong argillic, plugged with clay, truncated
35.5 - 36.8	2Btb2 / 2BCb	stratified, silty, weak
36.8 - 37.2	2Cb scour	massive scour, gravelly
37.2 - 38.5	3Btb	strong argillic, sandy, well oxidized, truncated
38.5 - 39	3BCb	massive, weak, gravelly scour
39 - 39.5	4Btb	strong argillic, sandy, well oxidized, truncated
39.5 - 41.8	4BCb	massive, weak, sandy scour
41.8 - 43.8	5Btb	strong argillic, sandy, well oxidized, truncated
43.8 - 45	--	No Recovery
45 - 46.6	5Cb scour	massive scour
46.6 - 47.9	6BCb	massive, weak
47.9 - 48.9	6Cb scour	massive scour
48.9 - 50	--	No Recovery
50 - 54.3	7Btb1	strong argillic, plugged with clay, well oxidized, truncated
54.3 - 57	7Btb2	strong argillic, plugged with clay, well oxidized
57 - 62	7Btb3	strong argillic, plugged with clay, gravelly
62 - 66.9	7BCb lam1	crudely stratified (stacked), gravelly with MnO
66.9 - 70	--	No Recovery
70 - 70.9	7BCb2	massive scour
70.9 - 73.9	8Btb1	strong argillic, plugged with clay, well oxidized, truncated
73.9 - 75.4	8Btb2 / 9BCb	weak argillic, gravelly, well oxidized
75.4 - 76.3	9ABb / 9Btb1	strong argillic, plugged with clay, organic rich, truncated
76.3 - 80.7	9Btb2	strong argillic, plugged with clay, well oxidized
80.7 - 85.5	9Btb3 / 9BCb	weak argillic, gravelly, well oxidized
85.5 - 88.5	10Btb1	strong argillic, plugged with clay, gravelly, well oxidized
88.5 - 89.7	10Btb2 / 10BCb	weak argillic, gravelly

Table 5.3

Depth (Ft)	Horizon	Summary Description of Transect A; Boring 9 (Cont.)
89.7 - 92.4	11Btb1	strong argillic, plugged with clay, well oxidized
92.4 - 95	11BCb lam	crudely stratified (stacked), sandy with gravel
95 - 98.8	12Btb1	strong argillic, plugged with clay, strong mottles, truncated
98.8 - 100	12BCb lam	stratified, sandy
100 - 100.9	13Btb	strong argillic, strong mottles, truncated
100.9 - 101.7	13BCb	massive, weak, well oxidized
101.7 - 103.5	14Btb	strong argillic, truncated
103.5 - 105	14BCb lam	stratified, sandy, well oxidized
105 - 107.5 +	14Cb scour	massive scour

Table 6.1
Transect A - AMEC Boring 3

Depth (Ft)	Horizon	Summary Description of Transect A; AMEC Boring 3
0 - 14.5	Af	Artificial Fill
14.5 - 20.5	Btj	silty, moderate oxidation, clay stains
20.5 - 24.25	Cox	nested scour, gravel and silt lenses
24.25 - 25	2Btj	silty, moderate oxidation, clay stains
25 - 27.5	2Cox	scour, gravel rich, coarse-grained
27.5 - 29	3Btj	silty, moderate oxidation, clay stains
29 - 33.8	4ABt/4Bt	organic and clay rich, coarser-grained, moderate oxidation
33.8 - 40.5	4BCredox1	silty, fine-grained w/ sparse gravel, moderately strong redox
40.5 - 46	4BC/4Credox2	coarser-grained, $CaCO_3$ fine nodules, moderate redox
46 - 56	4Cgl	coarse-grained, gravelly with oxidized rip up clasts?
56.5 - 61	5BCredox1	silty, fine-grained w/ sparse gravel, strong redox
61 - 68.5	5BCredox2	fine-grained w/ fine $CaCO_3$ concretions, strong redox
68.5 - 77	5BCox	clayey, common fine $CaCO_3$ concretions, moderate redox
77 - 91.8	6Cox1	silty, fine-grained w/ clay laminations, moderate oxidation
91.8 - 100	6Cox2	coarse-grained scour, moderate oxidation
100 - 101.5	6C3	coarse-grained scour, gravel rich
101.5 +	Lakewood Formation	Poorly lithified bedrock.

Table 6.2
Transect A - AMEC Boring 2

Depth (Ft)	Horizon	Summary Description of Transect A; AMEC Boring 2
0 - 19	Af	Artificial Fill
19 - 29.5	Btj	silty, moderate oxidation, clay stains
29.5 - 35	2ABt/2Bt	silty, organic rich, moderate oxidation
35 - 37	2BC/Bt gl	silty, fine-grained, slight redox
37 - 42	2BCredox	silty, fine-grained, moderate redox
42 - 42.5	2Cox	sandy scour, gravel rich
42.5 - 47	3BC redox	sandy, coarse-grained. Fines upwards, moderate redox
47 - 55.5	3Cox	sandy, coarse-grained, well oxidized, fines upwards
55.5 - 62	Lakewood Formation	Poorly lithified bedrock.

Table 6.3
Transect A - AMEC Boring 8

Depth (Ft)	Horizon	Summary Description of Transect A; AMEC Boring 8
0 - 18	Af	Artificial Fill
18 - 20	Btj	silty, moderate oxidation, clay stains
20 - 26.6	Cox	nested scour, gravel and silt lenses
26.6 - 27.5	2Btj	silty, moderate oxidation, clay stains
27.5 - 28.3	2Cox	scour, gravel rich, coarse-grained
28.3 - 31.8	3Btj	silty, moderate oxidation, clay stains
31.8 - 34.8	4ABt/4Bt	silty, organic rich, moderate oxidation
34.8 - 50	4BC 4C ox	sandy scour, coarse-grained, silt and gravel rich lenses
50 +	Lakewood Formation	Poorly lithified bedrock.

Table 7.1

Soil Description - Transect B; Boring 1

Depth (Ft)	Horizon	Transect B; B-1 Description
0 - 5.0	NR	No Recovery - no sample
5.0 - 5.2	Btj / BC	Dark yellowish brown (10YR 3/4m, mixed), loam, massive, slightly oxidized, slightly hard to hard, friable, slightly sticky, slightly to moderately plastic, coarse-grained poorly sorted sand, few to common fine slate gravel, few fine clay films on ped faces and coating gravel, clear lower boundary to;
5.2 - 6.0	2ABb	Very dark grayish brown (10YR 3/2m mixed), silt loam, massive, organic rich, hard to very hard, friable to firm, moderately sticky, moderately to very plastic, fine-grained well sorted sand, common moderately thick humus films on ped faces, gradational lower boundary to;
6.0 - 9.0	2Btb	Dark brown (10YR 3/3m, mixed), loam, massive, slightly oxidized, very hard, friable, slightly to moderately sticky, slightly to moderately plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces, clear lower boundary to;
9.0 - 10.0	3ABb/3Btb1	Very dark grayish brown (10YR 3/2m mixed), loam, massive, organic rich, very hard, friable, slightly to moderately sticky, moderately plastic, fine-grained well sorted sand, common fine and very few moderately thick clay films on ped faces, gradational lower boundary to;
10.0 - 15.2	3Btb2	Dark yellowish brown (10YR 3/4m, mixed), silt loam, massive, moderately well oxidized, hard to very hard, friable to firm, moderately sticky, moderately to very plastic, fine-grained well sorted sand, common to many fine and common moderately thick clay films on ped faces, few fine MnO nodules in matrix and fine webbing common on ped faces, gradational lower boundary to;
15.2 - 18.4	3Btb3	Dark grayish brown (10YR 4/2m, mixed), silt loam, massive, strongly gleyed, weakly oxidized, slightly hard to hard, firm, very sticky, moderately to very plastic, very fine-grained very well sorted sand, common fine and few moderately thick clay films on ped faces, few fine MnO nodules in soil matrix, gradational lower boundary to;
18.4 - 20.0	3Btb4	Dark yellowish brown (10YR 3/4m, mixed), loam to clay loam, faintly laminated, moderately well oxidized, partially gleyed, hard to very hard, firm, very sticky, moderately to very plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces, few fine MnO nodules in matrix and fine webbing common on ped faces, no recovery to;
20.0 - 24.1	3BCb ox	Dark yellowish brown (10YR 3-4/4m, mixed), sandy loam, massive, hard, friable, slightly sticky, slightly plastic, fine-grained well sorted sand, very few fine and few very fine thick clay films on ped faces, slightly mottled and well gleyed, fine MnO webbing common on ped faces, basal (gravel-rich) scour, abrupt lower boundary to;
24.1 - 29.2	4Btb	Dark yellowish brown (10YR 4/4m, mixed), loam to clay loam, faintly laminated, moderately well oxidized, hard to very hard, friable to firm, moderately sticky, moderately to very plastic, fine- to medium-grained moderately well sorted sand, many fine and common moderately thick clay films on ped faces, clear lower boundary to;
29.2 - 34.1	4BCb lam	Yellowish brown (10YR 5/4m, mixed), loamy sand and sandy loam, laminated (4" to 6" thick), moderately well oxidized, slightly hard, friable, slightly sticky, non- to slightly plastic, fine- to medium-grained moderately well sorted sand, alternates between sandy and clayey lams, abrupt lower boundary to;
34.1 - 36.2	4Cb scour	Brown (10YR 5/3m, mixed), loamy sand, massive, loose to soft, very friable, non-sticky, non-plastic, medium-grained moderately well sorted sand, abrupt lower boundary to;
36.2 - 37.9	5BCb lam	Yellowish brown (10YR 5/4m, mixed), sandy loam and loam, faintly laminated (0.5" to 3" thick), moderately well oxidized, slightly hard, friable, slightly sticky, non- to slightly plastic, fine-grained well sorted sand, abrupt lower boundary to;

Table 7.1

Depth (Ft)	Horizon	Transect B; B-1 Description (Cont.)
37.9 - 50.25	6BCb lam	Dark Grayish brown (10YR 4/2m, mixed), silt loam, finely laminated (varve like), locally well oxidized (in lams), hard, firm, moderately sticky, moderately to very plastic, very fine-grained very well sorted sand, localized MnO-rich zones (in lams), abrupt lower boundary to;
50.25 - 50.7	6Cb scour	Brown (10YR 4/3m, mixed), loamy sand to sandy loam, massive, slightly oxidized, loose, very friable, non-sticky, non-plastic, medium-grained moderately well sorted sand, abrupt lower boundary to;
50.7 - 59.2	7Btb	Dark grayish brown (10YR 4/2m, mixed), loam, finely laminated, moderately well oxidized and partially reduced, hard to very hard, firm, moderately sticky, moderately plastic, very fine-grained very well sorted sand, common fine and few moderately thick clay films on ped faces, abrupt lower boundary to;
59.2 - 60.3	7BCb / 7C ox scour	Dark brown (10YR 3/3m, mixed), sandy loam, massive, slightly oxidized, slightly hard, friable, slightly sticky, non- to slightly plastic, coarse-grained poorly sorted sand, abrupt lower boundary to;
60.3 - 63.8	8ABb / 8Btb1	Very dark grey (10YR 3/1m, mixed), clay loam, massive, organic rich, very hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, few to common fine and few moderately thick clay or humus films on ped faces, gradational lower boundary to;
63.8 - 67.5	8Btb2	Dark grayish brown (10YR 4/2m, mixed), clay loam, faintly bedded to massive, strongly gleyed (reduced), hard to very hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, few fine and moderately thick clay films on ped faces, clear lower boundary to;
67.5 - 71.4	8Btb3	Dark yellowish brown (10YR 4/4m, mixed) and Dark grayish brown (10YR 4/2m, mixed), loam, crudely laminated, well oxidized and strongly reduced (gleyed), hard to very hard, firm, very sticky, very plastic, fine-grained well sorted sand, many fine, common moderately thick and few thick clay films on ped faces, carbonate stage 1+ to 2, common fine and medium nodules in matrix and basal calcium carbonate layer (0.25' thick), abrupt lower boundary to;
71.4 - 75.5	9Btb1	Dark yellowish brown (10YR 4/4m, mixed), clay loam, massive, moderately well oxidized and strongly reduced (gleyed) along fractures, hard to very hard, friable, very sticky, very plastic, medium- to coarse-grained poorly sorted sand, common fine gravel, many fine, common moderately thick, and few thick clay films on ped faces, calcium carbonate stage 1, common fine nodules in matrix and common coatings along fractures, gradational lower boundary to;
75.5 - 79.5	9BCb lam / 9Btb2	Brown (10YR 4/3 m, mixed), silty clay loam and silt loam, massive to faintly laminated, slightly oxidized, very hard, firm, moderately to very sticky, very plastic, very fine-grained very well sorted sand, common fine and moderately thick clay films on ped faces, calcium carbonate stage 1-, few fine nodules in matrix, clear lower boundary to;
79.5 - 91	10Btb1	Dark yellowish brown (10YR 4/4m, mixed), clay loam, massive, thick, moderately well oxidized and strongly reduced (gleyed) along fractures, very hard, friable to firm, very sticky, very plastic, fine-grained well sorted sand, many fine and common moderately thick and few thick clay films on ped faces, calcium carbonate stage 1-, few fine nodules in matrix and faint coatings along fractures, gradational lower boundary to;
91 - 93.5	10Btb2 / 10BCb	Brown (10YR 4/3m mixed), loam, massive, slightly oxidized and partially reduced (gleyed), hard, friable, moderately sticky, very plastic, fine-grained well sorted sand, few to common fine and few moderately thick clay films on ped faces, calcium carbonate stage 1+, common fine and medium nodules in matrix, clear lower boundary to;

Table 7.1

Depth (Ft)	Horizon	Transect B; B-1 Description (Cont.)
93.5 - 95.0+	11Btb1	Dark yellowish brown (10YR 4/4m, mixed), clay loam, massive, moderately well oxidized, slightly hard to hard, firm, moderately to very sticky, very plastic, very fine-grained very well sorted sand, few to common fine and moderately thick and very few thick clay films on ped faces, calcium carbonate stage 1+ to 2, many fine nodules in matrix and common fine veinlets, undetermined lower boundary.

Table 7.2
Soil Development Index Calculation Sheet
Transect B; Boring 1

Unit	Thickness (Feet)	Color				Texture		Consistence				Clay Films		Horizon Values	Mean Hor. Values
		Dry		Moist				Dry		Wet					
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Tran B; Boring 1															
Btj / BC	0.2	n.d.	0	10YR 3/4	0.1	l	0.5	sh-h	0.50	ss, ps-p	0.42	1fpf, 1fcl	0.37	0.38	0.08
2ABb	0.8	n.d.	0	10YR 3/2	0	sil	0.67	h-vh	0.7	s, p-vp	0.75	2mkpf	0.4	0.50	0.40
2Btb	3.0	n.d.	0	10YR 3/3	0	l	0.5	vh	0.8	ss-s, ps-p	0.50	2fpf, 1mkpf	0.5	0.46	1.38
3ABb/3Btb1	1.0	n.d.	0	10YR 3/2	0	l	0.5	vh	0.8	ss-s, p	0.58	2fpf, v1mkpf	0.45	0.47	0.47
3Btb2	5.2	n.d.	0	10YR 3/4	0.1	sil	0.67	h-vh	0.7	s, p-vp	0.75	2-3fpf, 2mkpf	0.58	0.56	2.91
3Btb3	3.2	n.d.	0	10YR 4/2	0	l-cl	0.58	sh-h	0.5	vs, p-vp	0.92	2fpf, 1mkpf	0.5	0.50	1.60
3Btb4	1.6	n.d.	0	10YR 3/4	0.1	sl	0.33	h-vh	0.7	vs, p-vp	0.92	2fpf, 1mkpf	0.5	0.51	0.82
3BCb ox	4.1	n.d.	0	10YR 3-4/4	0.1	l-cl	0.58	h	0.6	ss, ps	0.33	v1vfpf	0.2	0.36	1.48
4Btb	5.1	n.d.	0	10YR 4/4	0.1	sl-sl	0.25	h-vh	0.7	s, p-vp	0.75	3fpf, 2mkpf	0.6	0.48	2.45
4BCb lam	4.9	n.d.	0	10YR 5/4	0.1	ls	0.17	sh	0.40	ss, po-ps	0.25		0	0.18	0.90
4Cb scour	2.1	n.d.	0	10YR 5/3	0	sl-l	0.42	lo-so	0.10	so, po	0.00		0	0.10	0.22
5BCb lam	1.7	n.d.	0	10YR 5/4	0.1	sil	0.67	sh	0.40	ss, po-ps	0.25		0	0.28	0.48
6BCb lam	12.4	n.d.	0	10YR 4/2	0	sil	0.67	h	0.60	s, p-vp	0.75			0.40	4.99
6Cb scour	0.5	n.d.	0	10YR 4/3	0	ls-sl	0.25	lo	0.20	so, po	0.00		0	0.09	0.04
7Btb	8.5	n.d.	0	10YR 4/2	0	l	0.5	h-vh	0.70	s, p	0.67	3fpf, 2mkpf	0.6	0.49	4.20
7BCb / 7C ox scour	1.1	n.d.	0	10YR 3/3	0	sl	0.33	sh	0.40	ss, po-ps	0.25		0	0.20	0.22
8ABb / 8Btb1	3.5	n.d.	0	10YR 3/1	0	cl	0.67	vh	0.80	vs, vp	1.00	1-2fpf, 1mkpf	0.48	0.59	2.07
8Btb2	3.7	n.d.	0	10YR 4/2	0	cl	0.67	h-vh	0.70	vs, vp	1.00	1fpf, 1mkpf	0.47	0.57	2.10
8Btb3	3.9	n.d.	0	10YR 4/4	0.1	l	0.5	h-vh	0.70	vs, vp	1.00	3fpf, 2mkpf, 1kpf	0.8	0.62	2.42
9Btb1	4.1	n.d.	0	10YR 4/4	0.1	cl	0.67	h-vh	0.70	vs, vp	1.00	3fpf, 2mkpf, 1kpf	0.8	0.65	2.68
9BCb lam / 9Btb2	4.0	n.d.	0	10YR 4/3	0	sicl	0.83	vh	0.80	s-vs, vp	0.92	2fpf, 2mkpf	0.65	0.64	2.56
10Btb1	11.5	n.d.	0	10YR 4/4	0.1	cl	0.67	vh	0.80	vs, vp	1.00	3fpf, 2mkpf, 1kpf	0.8	0.67	7.75
10Btb2 / 10BCb	2.5	n.d.	0	10YR 4/3	0	l	0.5	h	0.60	s, vp	0.83	1-2fpf, 1mkpf	0.52	0.49	1.23
11Btb1	1.5	n.d.	0	10YR 4/4	0.1	cl	0.67	sh-h	0.5	s-vs, vp	0.92	1-2fpf, 1-2mkpf, v1kpf	0.7	0.58	0.87

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.38**	**0.08**	**2.65**	**0.1**	**0.37**	**1 - 4**	**1 - 4**
Buried Soil 1	**0.50**	**1.78**	**3.28**	**0**	**0.90**	**8 - 15**	**9 - 19**
Buried Soil 2	**0.56**	**7.28**	**3.37**	**0.3**	**2.22**	**30 - 70**	**39 - 89**
Buried Soil 3	**0.48**	**3.57**	**2.06**	**0.2**	**0.60**	**8 - 15**	**47 - 104**
Buried Soil 4	**0.28**	**0.48**	**1.99**	**0.1**	**0.00**	**1 - 4**	**48 - 108**
Buried Soil 5	**0.40**	**5.03**	**2.75**	**0**	**0.00**	**4 - 8**	**52 - 116**
Buried Soil 6	**0.49**	**4.41**	**3.22**	**0**	**0.60**	**8 - 15**	**60 - 131**
Buried Soil 7	**0.62**	**6.58**	**4.15**	**0.1**	**1.75**	**30 - 70**	**90 - 201**
Buried Soil 8	**0.65**	**5.24**	**4.53**	**0.1**	**1.45**	**30 - 70**	**120 - 271**
Buried Soil 9	**0.67**	**8.98**	**4.49**	**0.1**	**1.32**	**30 - 70**	**150 - 341**
Buried Soil 10	**0.58**	**0.87**	**4.05**	**0.1**	**0.58**	**15 - 30**	**165 - 371**

Table 8.1

Soil Description - Transect B; Boring 3

Depth (Ft)	Horizon	Transect B; B-3 Description
0 - 5	NR	No Recovery - no sample
5.0 - 6.1	Bt1	Dark grayish brown (10YR 4/2m mixed), loam to clay loam, slightly oxidized, slightly hard, friable, moderately sticky, moderately plastic, coarse-grained poorly sorted sand, few to common fine slate gravel, few to common fine clay films on ped faces, gradational lower boundary to;
6.1 - 7.0	BC ox / Bt2	Dark yellowish brown (10YR 3/4m, mixed), clay loam, moderately well oxidized, soft to slightly hard, friable, moderately sticky, very plastic, coarse-grained poorly sorted sand, few very fine clay films (or stains) and sylans on ped faces, clear lower boundary to;
7.0 - 8.0	2Btb1	Dark yellowish brown (10YR 4/4m, mixed), clay loam, massive, moderately well oxidized, slightly hard to hard, friable, moderately to very sticky, very plastic, coarse-grained poorly sorted sand, few fine clay films on ped faces, calcium carbonate stage 1- few fine nodules, clear lower boundary to;
8.0 - 9.0	2BCb1	Dark yellowish brown (10YR 4/4m, mixed), sandy loam to loam, massive, moderately well oxidized, soft to slightly hard, friable, slightly sticky, slightly plastic, coarse-grained poorly sorted sand, few very fine clay films (or stains) on ped faces, calcium carbonate stage 1- to 1 few to common fine nodules, clear lower boundary to;
9.0 - 11.5	3Btb1	Brown (10YR 4/3m, mixed), clay loam, massive, moderately well oxidized, hard to very hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, common to many fine, common moderately thick, and few thick clay films on ped faces, gradational lower boundary to;
11.5 - 11.9	3Btb2	Dark brown (10YR 3/3m, mixed), loam to clay loam, massive, slightly oxidized, hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, few to common fine and few moderately thick clay films on ped faces, clear lower boundary to;
11.9 - 15.3	4Btb1	Dark yellowish brown (10YR 4/4m, mixed), clay loam, massive, moderately well oxidized, hard to very hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, many fine, common moderately thick, and few thick clay films on ped faces, few to common fine MnO nodules in soil matrix, gradational lower boundary to;
15.3 - 20.2	4BCkb1	Brown (10YR 4/3m, mixed), loam, massive, slightly oxidized, slightly hard to hard, friable, moderately sticky, slightly plastic, fine-grained well sorted sand, few fine gravel, calcium carbonate stage 1- to 1 few to common very fine and fine nodules in soil matrix; abrupt lower boundary to;
20.2 - 23.5	4BCb2 lam	Brown (10YR 4/3m, mixed), loam, crudely bedded or thickly laminated, slightly oxidized, soft to slightly hard, friable to very friable, non- to slightly sticky, non- to slightly plastic, coarse-grained poorly sorted sand, basal scour bed contains common fine slate gravel, common fine MnO nodules in coarser beds; abrupt lower boundary to;

Table 8.1

Depth (Ft)	Horizon	Transect B; B-3 Description (Cont.)
23.5 - 25.6	5Btb	Dark yellowish brown (10YR 3/4m, mixed), silty clay loam, finely bedded or laminated (varve like), well oxidized and gleyed in varves, hard to very hard, firm, very sticky, very plastic, very fine-grained very well sorted sand, many fine and common moderately thick clay films on ped faces, clear lower boundary to;
25.6 - 27.3	5BCb1 lam	Brown and Dark brown (10YR 4/3 and 3/3m, mixed), loam, crudely bedded or laminated (lams are 3"-5" thick), slightly oxidized, soft to slightly hard, friable to firm, slightly to moderately sticky, slightly plastic, fine-grained well sorted sand, localized common fine MnO nodules in lams; clear lower boundary to;
27.3 - 28.5	5BCb2 lam	Dark yellowish brown (10YR 4/4m, mixed), loam, crudely stratified or laminated (lams are 3"-5" thick), slightly oxidized, slightly hard, friable, slightly sticky, slightly plastic, fine-grained well sorted sand, clear lower boundary to;
28.5 - 30.0	6Btb	Dark yellowish brown (10YR 3/4m, mixed), loam to clay loam, finely bedded or laminated (varve like), slightly oxidized and partially gleyed in varves, hard, firm, slightly to moderately sticky, moderately plastic, fine-grained well sorted sand, common fine and few moderately thick clay films on ped faces, common MnO veinlets on ped faces, no recovery to;
30.0 - 30.5	6Cb scour	Dark brown (10YR 3/3m, mixed), sandy loam, massive, slightly oxidized and gleyed, slightly hard, friable, slightly sticky, non- to slightly plastic, medium-grained moderately well sorted sand, few fine MnO nodules in soil matrix, gradational lower boundary to;
30.5 - 33.6	7Btb trun	Dark yellowish brown (10YR 4/4m, mixed), loam, faintly laminated (irregular spacing), moderately well oxidized, very hard, firm, slightly to moderately sticky, slightly plastic, fine-grained well sorted sand, common fine and moderately thick clay films on ped faces, common MnO webbing on ped faces, gradational lower boundary to;
33.6 - 43.1	7BCb lam	Yellowish brown (10YR 5/4m, mixed), loam, faintly laminated (irregular spacing), well oxidized, slightly hard to hard, friable, slightly sticky, slightly plastic, fine-grained well sorted sand, common MnO webbing on ped faces, clear lower boundary to;
43.1 - 50.2	8BCb lam	Dark yellowish brown (10YR 4/4m, mixed), silty clay loam, finely laminated, moderately well oxidized, hard, firm, moderately sticky, moderately to very plastic, very fine-grained very well sorted sand, common MnO webbing on ped faces, abrupt lower boundary to;
50.2+	Lakewood	Bedrock

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Table 8.2

Soil Development Index Calculation Sheet
Transect B; Boring 3

Unit	Thickness (Feet)	Color				Texture		Consistence				Clay Films		Horizon Values	Mean Hor. Values
		Dry		Moist				Dry		Wet					
Raw Alluvium	*3*	*2.5Y 7/2*	*X/10*	*10YR 6/3*	*X/10*	*s*	*X/6*	*lo*	*X/5*	*so*	*X/6*	*0*	*X/15*		
Transect B; Boring 3															
Bt1	1.1	n.d.	0	10YR 4/2	0	l-cl	0.58	sh	0.40	s, p	0.67	1-2fpf	0.3	0.39	0.43
BC ox / Bt2	0.9	n.d.	0	10YR 3/4	0.1	cl	0.67	so-sh	0.3	s, vp	0.83	v1fpf	0.23	0.43	0.38
2Btb1	1	n.d.	0	10YR 4/4	0.1	cl	0.67	sh-h	0.5	s-vs, vp	0.92	1fpf	0.27	0.49	0.49
2BCb1	1	n.d.	0	10YR 4/4	0.1	sl-l	0.42	so-sh	0.3	ss, ps	0.33	v1fpf	0.23	0.28	0.28
3Btb1	2.5	n.d.	0	10YR 4/3	0	cl	0.67	h-vh	0.7	vs, vp	1.00	2-3fpf, 2mkpf, 1kpf	0.78	0.63	1.58
3Btb2	0.4	n.d.	0	10YR 3/3	0	l-cl	0.58	h	0.6	vs, vp	1.00	1-2fpf, 1mkpf	0.48	0.53	0.21
4Btb1	3.4	n.d.	0	10YR 4/4	0.1	cl	0.67	h-vh	0.7	vs, vp	1.00	3fpf, 2mkpf, 1kpf	0.8	0.65	2.22
4BCkb1	4.9	n.d.	0	10YR 4/3	0	l	0.5	sh-h	0.5	s, ps	0.5		0	0.30	1.47
4BCb2 lam	3.3	n.d.	0	10YR 4/3	0	l	0.5	so-sh	0.3	so-ss, po-ps	0.17		0	0.19	0.64
5Btb	2.1	n.d.	0	10YR 3/4	0.1	sicl	0.83	h-vh	0.70	vs, vp	1.00	3fpf, 2mkpf, 1kpf	0.8	0.69	1.44
5BCb1 lam	1.7	n.d.	0	10YR 4/3	0	l	0.5	so-sh	0.30	ss-s, ps	0.42			0.24	0.41
5BCb2 lam	1.2	n.d.	0	10YR 4/4	0.1	l	0.5	sh	0.40	ss, ps	0.33		0	0.27	0.32
6Btb	1.5	n.d.	0	10YR 3/4	0.1	l-cl	0.58	h	0.60	ss-s, p	0.58	2fpf, 1mkpf	0.5	0.47	0.71
6Cb scour	0.5	n.d.	0	10YR 3/3	0	sl	0.33	sh	0.40	ss, po-ps	0.25		0	0.20	0.10
7Btb trun	3.1	n.d.	0	10YR 4/4	0.1	l	0.5	vh	0.80	s, ps	0.50	2fpf, 2mkpf	0.54	0.49	1.51
7BCb lam	9.5	n.d.	0	10YR 5/4	0.1	l	0.5	sh-h	0.50	ss, ps	0.33		0	0.29	2.72
8BCb lam	7.1	n.d.	0	10YR 4/4	0.1	sicl	0.83	h	0.60	s, p-vp	0.75		0	0.46	3.24

INDEX VALUES AND DETERMINED AGES (ka)

Soil Member	MHI	Mean Soil Index	SDI @ 7 feet	Color Index	Clay Film Index	Soil Age Estimate ka	Section Age Estimate ka
Surface Soil	**0.43**	**0.81**	**2.84**	**0.1**	**0.43**	**8 - 15**	**8 - 15**
Buried Soil 1	**0.49**	**0.77**	**2.69**	**0.2**	**0.77**	**8 - 15**	**16 - 30**
Buried Soil 2	**0.63**	**1.79**	**4.32**	**0**	**1.16**	**15 - 30**	**31 - 60**
Buried Soil 3	**0.65**	**4.33**	**6.07**	**0.1**	**0.80**	**30 - 70**	**61 - 130**
Buried Soil 4	**0.69**	**2.17**	**3.04**	**0.2**	**0.80**	**15 - 30**	**76 - 160**
Buried Soil 5	**0.47**	**0.81**	**2.82**	**0.1**	**0.50**	**8 - 15**	**84 - 175**
Buried Soil 6	**0.49**	**4.23**	**2.35**	**0.2**	**0.54**	**4 - 8**	**88 - 183**
Buried Soil 7	**0.46**	**3.24**	**3.19**	**0.1**	**0.00**	**4 - 8**	**92 - 191**

Table 9.1
Transect B - Boring 2

Depth (Ft)	Horizon	Summary Description of Transect B; Boring 2
0 - 5.0	--	No Recovery
5.0 - 6.8	Btj / BC	weak argillic, truncated
6.8 - 9.5	2Btb	strong argillic, plugged with clay, truncated
9.5 - 10.2	3ABb/3Btb1	strong argillic, plugged with clay, organic rich
10.2 - 16.0	3Btb2	strong argillic, plugged with clay, well oxidized
16.0 - 17.1	3Cb scour	gravel rich scour
17.1 - 20	4BCb lam	crudely laminated with gravel
20 - 20.5	4Cb scour	gravel rich scour, slightly oxidized
20.5 - 21.1	5Btb	thin argillic, plugged with clay, truncated
21.1 - 25.2	5BCb lam	crudely laminated with clay and gravel
25.2 - 26.6	6BCb lam1	thickly laminated, sandy, moderate redox
26.6 - 30.6	6BCb lam2	thickly laminated, sandy, moderately reduced
30.6 - 36	7BCb lam / 7Btb	thinly laminated (varve like), clayey, moderate redox
36 - 42.8	8BCb lam	thickly laminated, sandy
42.8 - 43.3	8Cb scour	massive scour
43.3 - 44.7	9Btb / BCb lam	thinly laminated (varve like), silty
44.7 - 46	9Cb scour	massive sandy scour
46 - 59	10Btb	strong argillic, plugged with clay, organic rich, truncated
59 - 60	10Cb scour	massive scour
60 - 70.5	11Btb	strong argillic, plugged with clay, well oxidized, truncated
70.5 - 75.5	12Btb	strong argillic, gravel rich, truncated
75.5 - 80.5	13BCb lam1	thinly laminated (varve like), clayey, with MnO, truncated
80.5 - 85+	13BCb lam2	thinly laminated (varve like), clayey, well oxidized

Table 9.2
Transect B - Boring 4

Depth (Ft)	Horizon	Summary Description of Transect B; Boring 4
0 - 5.0	--	No Recovery
5 - 5.7	Bt	strong argillic, plugged with clay, truncated
5.7 - 6.3	BC	massive, silty, slightly oxidized
6.3 - 8.4	2Btb	strong argillic with gravel, plugged with clay, well oxidized
8.4 - 10	2BCb	massive, sandy with gravel, moderately oxidized
10 - 10.9	2Cb	gravel rich scour
10.9 - 15.9	3ABb / 3Btb	strong argillic, plugged with clay, organic rich, truncated
15.9 - 17.4	3BCb	massive, silty, slightly oxidized
17.4 - 20.3	4Btb1	strong argillic, plugged with clay, well oxidized, truncated
20.3 - 24	4Btb2 / 4BCb1	weak argillic, silty, well oxidized
24 - 26.6	4BCb2	massive, sandy, slightly oxidized
26.6 - 29.5	5Btb	moderate argillic, silty, moderately oxidized
29.5 - 31.8	5BCb	massive, silty, slightly oxidized
31.8 - 34.5	6BCb lam	thinly laminated (varve like), silty
34.5 - 38.9	7BCb lam	thinly laminated (varve like), clayey
38.9 +	Lakewood Formation	Poorly lithified bedrock.

Table 9.3
Transect B - Boring 5

Depth (Ft)	Horizon	Summary Description of Transect B; Boring 5
0 - 5.0	--	No Recovery
5.0 - 8.2	Bt / Btj	weak argillic, truncated
8.2 - 10.3	BC	massive with gravel
10.3 - 11	C scour	massive scour
11 - 12.8	2ABb / 2Btb1	strong argillic, plugged with clay, organic rich, truncated
12.8 - 15	2Btb2	strong argillic, plugged with clay, well oxidized
15 - 16.3	2BCb	massive, silty, slightly oxidized
16.3 - 20	3Btb1	moderate argillic, silty
20 - 21.8	3Btb2 / 3BCb1	weak argillic, sandy, moderately oxidized
21.8 - 23.9	3BCb2	massive, silty, slightly oxidized
23.9 - 25.4	4Btb	weak argillic, silty
25.4 - 25.9	4BCb	massive, sandy, slightly oxidized
25.9 - 26.8	5Btb1	strong argillic, plugged with clay, organic rich, truncated
26.8 - 27.3	5Btb2 / 5BCb	weak argillic, silty, moderately oxidized
27.3 - 28.8	6ABb / 6Btb	strong argillic, plugged with clay, organic rich, truncated
28.8 +	Lakewood Formation	Poorly lithified bedrock.

Table 9.4
Transect B - Boring 6

Depth (Ft)	Horizon	Summary Description of Transect B; Boring 5
0 - 5.0	--	No Recovery
5.0 - 5.7	Btj / BC	weak argillic, silty, truncated
5.7 - 8.9	2Btb1	moderate argillic, hard
8.9 - 11.1	2Btb2 / 2BCb	moderate argillic, silty, moderately oxidized
11.1 - 22.5	3Btb	moderate argillic, silty, thick
22.5 - 26.2	3BCb lam	faintly laminated (varve like), clayey, well oxidized
26.2 - 28.9	4ABb / 4Btb	strong argillic, plugged with clay, reduced
28.9 +	Lakewood Formation	Poorly lithified bedrock.

Table 10.1
Transect B - AMEC Boring 5

Depth (Ft)	Horizon	Summary Description of Transect B; AMEC Boring 5
0 - 6	Af	Artificial Fill
6 - 6.5	AB t	Dark brown, organic rich, clayey
6.5 - 9	Bt1	oxidized, fine-grained
9 - 13	Bt2	less oxidized, fine-grained
13.5 - 21.2	Bt3/BC1	coarse-grained, partial redox
21.2 - 25.5	Bt4/BC2	finer-grained, moderate redox
25.5 - 27	2AB/Bt trun	clayey, organic rich, strong redox
27.5 - 33	2BCox1	silty, loose, strong redox
33 - 37.5	2BCox2	coarser-grained, strong redox
37.5 - 43.5	3C beach1	beach sand?, well sorted, rounded clasts
43.5 - 49	3C beach2	beach sand and colluvium?, well sorted, rounded clasts
49 - 52 +	3Cox beach3	beach sand?, well sorted, rounded clasts, well oxidized

Table 10.2
Transect B - AMEC Boring 6

Depth (Ft)	Horizon	Summary Description of Transect B; AMEC Boring 6
0 - 6	Af	Artificial Fill
6 - 14	Bt1	well oxidized, plugged with clay
14 - 19	Bt2	well oxidized, plugged with clay. Coarser-grained
19 - 21.5	2Bt1	moderate oxidation, fine-grained
21.5 - 24.25	2Bt2	moderate oxidation, coarser-grained
24.25 - 28.5	2Bt3/BC1	silty, slight redox
28.5 - 30.5	3AB	organic and clay rich, coarser-grained
30.5 - 39	3Bt1 redox	clayey, coarse-grained, strong redox
39 - 44	3Bt2 redox	silty, fine-grained, strong redox
44 - 47	3BC redox	silty, fine-grained, moderate redox
49 - 54	4Bt1 redox	fine-grained, mixed organics and MnO strong redox
54 - 64.25	4Bt2/BC redox	fine-grained, MnO, moderate to strong redox
64.25 - 66.5	5AB/5Bt1	clayey, fine-grained, mixed organics and MnO, slight redox
66.5 - 74	5Bt2 redox	clayey, fine-grained, MnO, moderate redox
74 - 100 +	Lakewood Formation	Poorly lithified bedrock.

Table 10.3
Transect B - AMEC Boring 7

Depth (Ft)	Horizon	Summary Description of Transect B; AMEC Boring 7
0 - 7.5	Af	Artificial Fill
7.5 - 9.2	Btj	silty, moderately oxidized, coarse-grained
9.2 - 16	2 Bt gl	clayey, fine-grained, reduced
16 - 25	3Bt 1&2	silty, fine-grained, slight redox
25 - 38.5	3BC ox	silty, coarser-grained, slight redox, locally laminated
38.5 - 41	4AB/4Bt1	clayey, fine-grained, well oxidized, organic rich
41 - 58.5	4Bt2	clayey, fine-grained, moderately oxidized
58.5 - 69.75	4BC redox	silty, coarse-grained, moderate redox
69.75 - 72	5AB/5Bt1	clayey, fine-grained, well oxidized, organic rich
72 - 74 +	5Bt2/BC	clayey, fine-grained, strong redox

Table 11. Soil Surface Relative-Age Estimates Summary Table

Profile Number	Soil Member	MHI Value	SDI Value	Clay Film	Relative Age (ka)
1 Transect A Boring 1	Surface Soil	0.36	1.16	0.7	4 - 8
	Buried Soil 1	0.51	3.04	0.5	19 - 38
	Buried Soil 2	0.58	3.52	0.6	34 - 68
	Buried Soil 3	0.56	1.84	0.6	42 - 83
	Buried Soil 4	0.41	2.36	0.3	50 - 98
	Buried Soil 5	0.22	1.28	0.0	51 - 102
	Buried Soil 6	0.64	3.58	2.0	66 - 132
	Buried Soil 7	0.65	4.27	2.5	96 - 202
	Buried Soil 8	0.61	3.90	1.1	111 - 232
	Buried Soil 9	0.62	3.54	0.6	126 - 262
	Buried Soil 10	0.57	2.41	0.4	141 - 292
	Buried Soil 11	0.55	2.92	1.1	156 - 322
2 Transect A Boring 4	Surface Soil	0.5	3.29	0.77	8 - 15
	Buried Soil 1	0.32	1.39	0.27	12 - 23
	Buried Soil 2	0.26	0.83	0.30	13 - 27
	Buried Soil 3	0.33	2.33	0.38	28 - 57
	Buried Soil 4	0.58	2.38	0.72	58 - 127
	Buried Soil 5	0.48	2.05	0.88	73 - 157
	Buried Soil 6	0.63	3.75	1.20	103 - 227
	Buried Soil 7	0.52	3.30	0.60	118 - 257
	Buried Soil 8	0.37	2.56	0.50	122 - 265
	Buried Soil 9	0.52	2.07	0.50	137 - 295
3 Transect A Boring 5	Surface Soil	0.56	1.93	0.97	8 - 15
	Buried Soil 1	0.21	0.85	0.00	9 - 19
	Buried Soil 2	0.35	2.43	0.30	24 - 49
	Buried Soil 3	0.61	3.84	1.44	54 - 119
	Buried Soil 4	0.36	1.53	0.00	58 - 127
4 Transect A Boring 7	Surface Soil	0.43	2.40	0.70	8 - 15
	Buried Soil 1	0.17	1.03	0.00	9 - 19
	Buried Soil 2	0.33	2.33	0.38	13 - 27
	Buried Soil 3	0.35	2.43	0.30	28 - 57
	Buried Soil 4	0.55	3.86	0.62	58 - 127
	Buried Soil 5	0.22	1.50	0.00	62 - 135

Table 11 (Cont.). Summary Table

Profile Number	Soil Member	MHI Value	SDI Value	Clay Film	Relative Age (ka)
5 Transect B Boring 1	Surface Soil	0.38	2.65	0.37	1 - 4
	Buried Soil 1	0.50	3.28	0.90	9 - 19
	Buried Soil 2	0.56	3.37	2.22	39 - 89
	Buried Soil 3	0.48	2.06	0.60	47 - 104
	Buried Soil 4	0.28	1.99	0.00	48 - 108
	Buried Soil 5	0.4	2.75	0.00	52 - 116
	Buried Soil 6	0.49	3.22	0.60	60 - 131
	Buried Soil 7	0.62	4.15	1.75	90 - 201
	Buried Soil 8	0.65	4.53	1.45	120 - 271
	Buried Soil 9	0.67	4.49	1.32	150 - 341
	Buried Soil 10	0.58	4.05	0.58	165 - 371
6 Transect B Boring 3	Surface Soil	0.43	2.84	0.43	8 - 15
	Buried Soil 1	0.49	2.69	0.77	16 - 30
	Buried Soil 2	0.63	4.32	1.16	31 - 60
	Buried Soil 3	0.65	6.07	0.80	61 - 130
	Buried Soil 4	0.69	3.04	0.80	76 - 160
	Buried Soil 5	0.47	2.82	0.50	84 - 175
	Buried Soil 6	0.49	2.35	0.54	88 - 183
	Buried Soil 7	0.46	3.19	0.00	92 - 191

Table 12. Comparison Soil Data Indices Value Summary

(McFadden) Mission Creek Soils	SDI At 7'	MHI	Reddening Index	Clay Film Index
S7 0-1000 yrbp	5.9	0.12	0	0
S5 4-13 ka	10.2	0.3	0.1	0
S4 13-70 ka	31.4	0.37	3.94	7.37
S2 70-250 ka	56.10	0.61	4.80	6.24
S2 250-700 ka	25.70	0.39	6.20	10.31

(Rockwell) Ventura River Basin Soils	SDI At 7'	MHI	Reddening Index	Clay Film Index
Qt3 4 - 8 ka	17	0.17	0.5	0
Qt4 10 -15 ka	27	0.43	2	4
Qt5a 15 – 20 ka	28	0.37	3.5	4.2
Qt5b 30 ka	32	0.46	5	7

(WLA) West Hollywood Buried Soils	SDI At 7'	MHI	Reddening Index	Clay Film Index
Qol1 100 ka	21.4	0.42	1.05	1.99
Qol2 100-300 ka	73.5	0.8	8.2	13.2

TABLE 13. Soil Field Description Abbreviation Key

Texture		Structure		Consistence						Clay Films		Calcium Carbonate (Pedogenic CaCO3)	
				Dry		Moist		Wet					
S	- sand	m	- massive	l	- loose	vfr	-very friable	so	non stickey	v1	veryfew	sl dis	slightly dissemenated
LS	- laomy sand	sg	- single grained	so	-soft	fr	-friable	ss	slightly stickey	1	few	I	slight coatings common on clast bottoms
SL	- sandy loam	**OR**		sh	-slightly hard	fi	-firm	s	moderately siteckey	2	common	II	moderately thick coatings on clast bottoms; few medium common fine noodeuses
L	- loam	1	- weak	h	-hard	vfi	-very firm	vs	very stickey	3	continuous	III	thick coatings common on clast bottoms, common medium nodules, common fine pendants, many fine nodules
CL	- clay loam	2	- moderate	vh	-very hard			**AND**		**AND**		VI	many thick coatings on clasts bottoms common coarse pendants few clasts completely enveloped
SCL	- sandy clay loam	3	- strong	eh	-extremely hard			po	non plastci	vn	stains	V	many thick coatings on clasts bottoms, many coarse pendants common clasts completely enveloped- petrocalcic
C	- clay	**AND**						ps	slightly plastic	n	thin	V+	many thick coatings on clasts bottoms, many coarse pendants many clasts completely enveloped, completely disseminated in matrix - petrocalcic
Si	- silt	vf	- very fine					p	moderately plastic	mk	moderately thick		
SiL	- silt loam	f	- fine					vp	very plastic	k	thick		
SiCL	- silt clay loam	m	- medium							**AND**			
SiC	- silty clay	c	- coarse							cl	coating clasts		
		vc	- very coarse							pf	ped faces		
		AND								br	brodgeing sand grains		
		gr	- granular							po	lining pores		
		pl	- platty										
		pr	-prismatic										
		abk	-angular blockey										
		sbk	- sub angular blockey										

Table 14. Cross Sectional Unit Relative Ages

Boring Transect	Boring Described	Soil Horizon	Profile Relative Age (ka)	Unit Relative Age (ka)
A	1	Buried soil 1 and 2	34 - 68	34 - 127
	4	Buried soil 3 and 4	58 - 127	
	5	Buried soil 2 and 3	54 - 119	
	7	Buried soil 3 and 4	58 - 127	
B	1	Buried soil 1	9 - 30	9 - 30
	3	Buried soil 1	16 - 30	
B	1	Buried soil 2	39 - 89	31 - 89
	3	Buried soil 2	31 - 60	

Beverly Hills High School
Active Fault Investigation
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Introduction

This report evaluates the potential for active faulting at the Beverly Hills High School (subject site). The evaluation is based on geological and geophysical data documented in the Century City Area Fault Investigation Report (CCAFIR) for the Westside Subway Extension Project and other published information relevant to faulting located in the vicinity of the subject site. Some ideas for additional data acquisition at the subject site to better define shallow surface deformation and faulting are presented.

Neotectonic Framework

Local Faults and Tectonic Deformation

Major faults located in the vicinity of Beverly Hills (Figure 1) include the west-trending Santa Monica and Hollywood faults, and the northwest-trending Newport-Inglewood Fault Zone (NIFZ). The Santa Monica and Hollywood faults are reverse-slip, but also include a component of left-slip (Dolan et al. 1995). These two faults accommodate north-directed shortening of the Peninsular Ranges structural province, which includes the Los Angeles Basin, as it impinges against the Western Transverse Ranges structural province. The Santa Monica Mountains in the Western Transverse Ranges have been uplifted by north-directed shortening over the past 700,000 years or so (Pasadenan Orogeny, T. Wright, 1991). In contrast, the northwest-trending NIFZ accommodates right-slip as part of the major San Andreas fault system in southern California due to the Pacific-North America transform relative motion.

The West Beverly Hills Lineament (WBHL), a northern extension of the Newport-Inglewood fault zone in the Los Angeles Basin (Tsutsumi et al. 2001), was recognized by a series of northwest-trending discontinuous east-facing scarps that cross the Beverly Hills area. The WBHL truncates the eastern end of the Santa Monica Fault and intersects the Hollywood Fault near the base of the Santa Monica Mountains. The east-facing scarps indicate that the crustal block to the west of the WBHL is relatively uplifted compared to the eastern block, where the Hollywood Basin exists. Although the WBHL lineament could be considered a tear fault located between the laterally-offset Santa Monica and Hollywood reverse faults, its location and northwest alignment suggest that it is more likely the continuation of the larger NIFZ that extends as far south as San Diego (Rose Canyon Fault) and beyond into northern Baja California.

The Hollywood Basin is one of the deepest Quaternary basins within the larger Los Angeles Basin, and is considered to be a pull-apart basin due to a releasing stepover in the Santa Monica - Hollywood fault system (Dolan et al. 1995). A left stepover is a releasing geometry in a left-slip fault zone. Thus, relative uplift west of the WBHL may result from subsidence of the Hollywood Basin as a stepover basin or from the reverse-slip component of the Santa Monica Fault that terminates at the WBHL. Termination bulges are common at stepover basins (Freund, 1971). A combination of these processes is likely to create the vertical deformation along the WBHL. Detailed shallow subsurface investigations are necessary to define the character and potential for active surface faulting along the West Beverly Hills Lineament.

Methods

Subsurface investigation of shallow structure that may include Holocene fault displacements (active faulting) are typically accomplished by trenching (paleoseismic trenching). In many areas, especially in an urban environment, it is difficult or impractical to dig trenches across developed properties. Geophysical methods provide a way to investigate the subsurface using remote sensing that does not disturb (disrupt) the ground surface significantly as occurs with trenching. Geophysical methods like seismic reflection or refraction profiling are often used to identify shallow subsurface strata (geological layers) and potential fault offset(s). However, geological ground truth is necessary to verify interpretations of geophysical data and obtain quantitative data on character, composition, and age of subsurface structure and stratigraphy. A series of transects (Figure 2) including geophysical profiles – seismic reflection profiles – and geological profiles using Cone Penetrometer Test (CPT) and borehole investigations were conducted for the Westside Subway Extension Project (Parsons Brinckerhoff, 2011). Offsets of subsurface layers interpreted in the seismic reflection profiles across the West Beverly Hills Lineament (WBHL) and consistent with offsets in layers projected through the CPT and borehole profiles were suggested to represent active faulting. The following section discusses our review and interpretation of these subsurface data and proposed fault traces.

Interpretation of Seismic Profiles

Fault interpretations are shown on migrated P-wave (and S-wave if good quality) seismic profiles in the Westside Subway Extension Project report (Parsons Brinkerhoff, 2011). Based on experience, migrated data have better resolution and faults show more distinct offsets on layered reflections. The profiles with interpretations were processed with a FX Predictive Deconvolution and Spectral Balancing applied to the stacked data (but not migrated). The FX process typically smooths the reflection data somewhat resulting in a more coherent reflection image. The downside is that faults may be smeared out of the image. However, several shallow faults are identified in the profiles and their existence is very likely, but their geometry and shallow extent is questionable as noted on the profiles. Highly variable near surface seismic velocities (statics) make shallow imaging difficult, but careful data processing provides reasonable seismic profiles for interpretation. The migration process is more sensitive to accurate velocity data, but use of reasonably accurate velocity structure that under-migrates data provides significant improvement in image quality, and helps to identify possible fault offsets. Severe shallow velocity variations may produce apparent subsurface geologic structure that is incorrect – turns synclines into anticlines, creates false horizon offsets such as velocity pull-downs. However, some shallow velocity variability may represent actual shallow fault structure – but channeling, other surface erosion, deposition, and compaction effects must be considered, too. As noted previously, it is necessary for direct geological investigation via trenching or borehole drilling to confirm faulting and recency of displacement.

A simple interpretation is to connect fault locations on one seismic profile to fault locations on another profile some distance away, but in complex fault zones these connections may be inaccurate. For this study, only two profiles cross the WBHL at a high angle (Figure 2), where fault identification is more readily accomplished, but these profiles are about 400-ft apart (or greater). Although both profiles show several possible shallow fault traces associated with the northeast-dipping monocline along the trend of the WBHL, the exact number of fault traces identified and the character of deformation and offset in the seismic profiles cannot be matched with confidence from one profile to the other. Actual surface fault rupture patterns observed in recent large earthquakes show complex patterns that would be impossible to predict based on only two profiles separated a few hundred feet apart. Nevertheless, the observations of a zone of faulting along with the northeast-dipping monocline at both profiles supports the interpretation that this zone is continuous on that northwest trend between the profiles. Additional geophysical profiles and geological investigations including trenches and boreholes across the projected zone of faulting are necessary to identify and locate possible “active” fault traces at the subject site.

Faults Identified Along AMEC Transect #2

The P-wave seismic reflection profile (Figure 3) shows good reflector continuity suitable for identification of possible shallow faulting; the S-wave profile suffers from substantial “noise” that disrupts the reflection signals and precludes confident interpretation of shallow faulting. On the P-wave profile, several possible shallow faults are interpreted between 1800-ft and 2500-ft along the Transect #2. The zone of faulting spans the width of the shallow northeast-dipping monocline that is shown most clearly by the strong reflection layers (about 0.12 to 0.14 sec twtt) identified as an unsaturated sand between saturated clay layers (based on borehole data). The intervening layer between the strong reflections thickens at the western edge of the monocline (about 1850-ft) possibly due to fault displacement. This layer thins slightly at the eastern edge of the fault zone where the dip of the monocline flattens out. One possible interpretation for the reflective horizons (unsaturated sands) is a marine terrace or ancient beach deposit. Such a stratigraphic sequence is inferred to have been deposited approximately horizontally at or near sea level. More detailed interpretation of this stratigraphic sequence cannot be attempted at this time without further data, but the primary observation that this surface is warped into the monocline and offset by shallow faults in the zone along the WBHL is signficant. Terminations of high-frequency shallow reflections are apparent and may indicate near surface fault offset. However, due to the poorer image quality at the shallowest levels below the ground surface, it cannot be conclusively demonstrated that the faulting reaches the ground surface or young alluvial layers that may be Holocene in age. The lack of obvious reflection terminations or offsets to the east of about 2400-ft is consistent with absence of significant shallow faulting in this area.

Consistent Observations (geological data) – Shallow fault offsets are identified on the CPT and borehole geologic section near 1850-ft, 2200-ft, and 2400-2500 ft, whereas apparent fault offsets on the P-wave seismic profile are identified near 1850-ft, 2050-ft, 2150-ft, 2300-ft and 2400-ft. Minor faults were identified in borehole T2E-B4 at 2290-ft (elev. 140-ft) which may correlate with the offsets in the P-wave seismic near 2300-ft. Fault offsets interpreted in the P-wave seismic at 2050-ft and 2150-ft may exist based on the CPT profiles, but were not shown on the geologic section. A major offset in the ground water level encountered during drilling was shown in this area. Unsaturated sand layer, at depth of 175.6-feet (elevation 97.4-feet), is interpreted to be San Pedro Sand on boring log T2E-B3. San Pedro Sand is not identified on the other boreholes (depths to 200-ft) along Transect #2E, consistent with deepening of this horizon to the east (northeast) into the Hollywood Basin.

Faults Identified Along AMEC Transect #4

Transect #4 includes good image quality for both the P-wave (Figure 4) and S-wave (Figure 5) seismic reflection profiles. The zone of shallow faulting is interpreted based upon reflection terminations and subtle offsets that may represent fault displacement along the WBHL trend. The northeast-dipping monocline is more clearly recognized in the data along Transect #4, especially in the S-wave data which have higher resolution and greater vertical exaggeration that amplifies the apparent dip. The thickening of the layer between two highly reflective sequences is even more pronounced along Transect #4 than in #2, and the top layer bulges upward above the west edge of the monocline. One possible (but not the only one) interpretation of this bulge is a barrier beach or sand bar. The location of this feature at the west edge of the WBHL suggests that the fault zone or some related zone of deformation was active at the time of the postulated beach deposition (and/or terrace formation). The lower surface of the reflective sequence is clearly warped by the monocline – inferred fault offsets are subtle in the P-wave profile, but more pronounced in the S-wave profile. In particular, the western edge of the monocline (200-ft to 400-ft) shows a highly disrupted zone of reflections in the S-wave profile that may indicate the more prominent fault zone at the crest of the monocline; a second zone of faulting with reflection offsets and terminations is apparent between 700-ft and 850-ft, which shows a subtle offset of the strong east-dipping reflector at about 0.32-sec to 0.34-sec twtt on the S-wave profile. A subtle zone with a couple of possible shallow faults is also apparent at about 500-ft to 550-ft on both profiles, with the trace at 500-ft more prominent on the S-wave profile. Although shallow reflection terminations and offsets are apparent at shallow depths on the two profiles, the higher resolution S-wave data do not show conclusive offsets in the upper 10-ft to 20-ft below the ground surface – partly due to the shallow imaging problems with variable velocity structure. Geological ground truth by excavation or borehole drilling are necessary to conclusively identify near-surface faulting that may be Holocene age associated with active fault traces.

Consistent Observations – the CPT and borehole geologic section shows a zone of faulting at the western edge of the northeast-dipping monocline, from about 300-ft to 600-ft along Transect #4. One shear zone was identified in borehole T4-B3 at about location 3+80 (depth 58-60 feet; elev. 200-202 feet) along Transect #4. Faulting interpreted near 800-ft on the seismic profiles appears to be below the depth reached by the CPT and borehole data. Two fault traces, queried at their shallow extent, are interpreted in the CPT profiles to extend into the Younger/Older Alluvial Fan Deposits on Transect #4 (locations 4+00 and 4+88). Offset of poorly-defined, shallow reflection layers in the seismic profiles (both P-wave and S-wave) may be interpreted. The interpreted (GeoVision) unmigrated seismic profiles show the shallowest fault traces to the west of location 400 ft along the transect, although the two inferred traces without queries correspond to the shallow traces on the CPT near locations 4+00 and 5+00. The migrated data show distinct offset of reflectors at shallow levels in this area, which also corresponds to the crest of the wedge above the east-dipping monocline. Therefore, the seismic data are consistent with the CPT profiles along Transect #4 in this area and shallow faulting may be present. The age of faulting remains to be determined.

Faults Identified Along AMEC Transect #7

Transect #7 crosses the WBHL at an oblique angle (Figures 2 & 6) and lies within the zone of the monocline for most of its length. Consequently, northwest-trending fault structure will be difficult to identify and side-swipe from offset layers may confuse the seismic image (and the interpreters). A strong northwest-dipping reflection sequence at about 0.16-sec to 0.21-sec twtt appears to cut across other reflectors with less dip – this character is typical of side-swipe and the interpreter cannot determine which reflections (if any) are located beneath the profile and which may be off to one side or the other in 2D seismic profiles. The strong reflection sequences at 0.10-sec to 0.14-sec twtt associated with the unsaturated sand layer is present on Transect #7 P-wave profile (Figure 6), but is more disrupted, less continuous and more offset than in the two southwest-northeast transects described above. This reflection character is consistent with the profile lying along and within the shallow fault zone associated with the WBHL. The apparent northwest dip of the strong reflections may be inconsistent with the northeast-dipping monocline at first glance, but may be a result of the subsidence to the north in the Hollywood Basin due to the left (releasing) step-over of the Santa Monica fault to the Hollywood fault. Thus, the true dip of the monocline is to the northeast, and part of the apparent dip along Transect #7 is actually fault offset – segments of the strong reflection sequences are nearly horizontal (excluding the side-swipe) and the southeast end has the upward bulge of the top reflection where it crosses Transect #4, at the west edge of the monocline. The largest offset apparent in the strong reflection sequences appears near 600-ft along the transect. The strong reflection sequences appear to terminate near the northwest end of the transect at about 700-ft. Fault offsets in the CPT and borehole geologic section are identified at about 100-ft, 300-ft, and 400-ft – there are clear offsets in the reflection sequences at the first two locations, but the last offset is more subtle in the P-wave seismic profile. The first two fault locations appear to bound the upward bulge area in the top of the strong reflection sequence. The character of the strong reflection sequence, with offsets, bulges, and monoclinal dip, may provide a good surface to image with 3-D seismic techniques so that the fault geometry and deformation could be determined more accurately.

Unresolved Issues Regarding Surface Fault Rupture Interpretations

Seismic reflection, CPT, and borehole profiles show a broad zone of faulting along the West Beverly Hills Lineament. Confident identification and accurate location of active fault traces, based on the criteria that Holocene deposits are offset (<10,000 yrs BP), is difficult to achieve. The following interpretation issues remain unsolved at this time:

Fault Activity and Mapped Locations of Fault Traces

- Conclusive evidence of Holocene surface fault rupture is absent.
  Existing seismic reflection profiles are unable to image the shallow subsurface where Holocene material exists. Shallow faulting is based on the CPT profiles and upward projection of fault traces identified in the seismic profiles, however, the age of deposits inferred to be offset, based on the CPT and borehole profiles, is not determined accurately. Therefore, conclusions regarding active faulting along the West Beverly Hills Lineament are premature and possibly an overly conservative assumption based on inadequate data.
- Map pattern of complex surface rupture is unresolved.
  Recent large earthquakes on low slip-rate faults show complex surface rupture patterns over a broad zone and are probably good analogs for the WBHL. For strike-slip faults, the surface rupture pattern often consists of complex zones of anastomosing and en echelon fault traces including both synthetic and antithetic shears (Figure 7; Tchalenko, 1970; Wilcox et al. 1973; Sowers et al. 1994; Treiman et al. 2002; Quigley et al. 2012). The simple interpretation in the CCAFIR connects fault traces in straight lines between points interpreted on the seismic/geologic transects, whereas more realistic fault patterns may involve series of left-stepping en echelon fault traces with north or northeast strike (synthetic or antithetic shears). Widely-spaced 2-D geological and geophysical transects are inadequate to map complex fault patterns accurately.
- Rare surface rupture recurrence times are inconsistent with other seismic risk criteria.
  Building codes for seismic resistant construction use 500-yr events for regular buildings, and 2500-yr events for special construction. Although no slip rate for the WBHL has been measured, the rate for large earthquakes on the Inglewood fault (NIFZ) is low (slip rate ~0.5 m/kyr; Freeman et al. 1992). Large events with significant surface rupture would have long recurrence times, 5,000 to 10,000 years. Evidence of prehistoric surface rupture events with recurrence intervals of several thousand years may be nearly impossible to find in areas of active erosion and alluvial fan deposition.
- If there are numerous traces, then the displacement per trace may be insignificant. Surface shear may be distributed and not on discrete faults or may be a combination of both as observed in recent large earthquakes on low slip-rate faults. This issue also makes it difficult to identify and map prehistoric surface fault ruptures.

Structural Character and Seismic Stratigraphy

- Vertical offset may be important for foundation damage. Southwest-side of the WBHL is uplifted, but not clearly defined by fault offset. Instead, there is a northeast-dipping monocline that appears to be offset by faulting with no consistent sense of vertical separation, typical of strike-slip fault zones. Indeed, the downslope side often shows relative uplift at the fault trace.
- There is a wedge of material between strong reflectors – is this a levee deposit, or barrier beach sand bar? P-S suspension logs suggest unsaturated sand layer–why is this thick in the fault zone? Wedge appears thicker and shallower on Transect #4 – farther south and downslope for channel system, but available data are inconclusive. [San Pedro Sand according to T2E-B3 boring log]
- Strong reflection layers deepen to northwest along South Moreno Drive, flat to north along Heath Avenue (Transect #7). A deeper strong reflection event on T-7 dips 170-200 ms, weak on T-4 – Is this sideswipe from building foundation or from offset layers on other side of fault? [Rough calculations: two-way reflection time is 510-ft to 600-ft away at 6000 ft/sec, 255'-300' at 3000 ft/sec. Building corner only 60'-200' away from T-7 so not cause of side-swipe unless surface velocity is very slow, <3000 ft/sec]
- Is the northeast-dipping monocline a result of north dip off the crest of the Wilshire Arch? Hollywood basin may be a combination of a left-slip releasing stepover sag (Santa Monica-Hollywood fault zone) and the syncline behind (north of) the Wilshire Arch.

- Based on recent fault trenching at the Beverly Hills High School site, the slope along the projection of the WBHL is underlain by old alluvial fan materials (R. Shlemon, pers. commun.). The slope appears to be the result of erosion or depositional processes as horizontal layering of surface deposits was observed. No conclusive evidence of folding was identified. This is consistent with the seismic profiles to the extent that there is an apparent depositional thickening of units above the monocline, although the shallow subsurface is not imaged in detail. Also, there appear to be some channels evident along or adjacent to the projected WBHL in the seismic data.
- Variable shallow P-wave velocity makes it difficult to prepare depth sections – some structure may be velocity pull-up/pull-down and not geological. P-wave seismic has strong velocity contrast at groundwater interface – low velocities and high variability above, roughly 6000 ft/sec below. The high variability of near surface material and seismic velocity make interpretation of the shallowest reflection image difficult. Prominent layered reflections are absent or highly disrupted in the shallow part of the seismic profile, which reduces confidence in the interpretation at shallow levels – hence the queries on the inferred faults at shallow depth. Direct observation of the shallow geology is required, via excavation or borehole, to accurately define the location, character and age of near surface faulting that may represent Holocene activity.

Discussion

Complex deformation may be expected along the WBHL, especially in the vicinity of the subject site, which is located adjacent to the termination of the Santa Monica Fault against the WBHL (near Santa Monica Boulevard). Typical fault character for strike-slip faults includes a map pattern of en echelon and anastomosing fault traces and a complex downward-convergent fault pattern in cross-section that is often called “flower structure” (Tchalenko, 1970; Harding, 1973; 1985; Wilcox et al. 1973). These patterns have been observed at all scales, from microscopic to megascopic including earthquake fault ruptures and large-scale fault systems. The ideal strike-slip fault with a narrow, well-defined, single fault trace is exceptional. Seismic reflection profiles obtained across the WBHL in the vicinity of the subject site confirm the complex pattern of faulting in cross-section, although the data are inadequate to clearly show downward-convergent faulting (flower structure). In fact, there are many observations with high-resolution seismic reflection profiles that image fault structure where individual fault traces do not converge but remain sub-parallel to the bottom of the seismic image, kilometers in depth.

Additional fault complexity at the subject site may result from interaction between the WBHL and the Santa Monica Fault. Termination of the Santa Monica Fault at the WBHL requires that the left-slip component diminishes as it approaches the termination or that some form of strain transfer occurs. The extension that has been inferred to produce the Hollywood Basin may be one aspect of the strain transfer from the Santa Monica fault to the Hollywood fault across the WBHL. The elevation difference across the WBHL produces a gravitational instability, too. The surface deformation resulting from these complex processes may produce complex surface fracturing (extensional) in addition to the southeast-dipping monocline (folding) and faulting that accommodates the three-dimensional strain field. Thus, we may see a component of normal faulting in addition to the right-slip expected on the NIFZ. Furthermore, there may be complex antithetic faulting, as is often observed along strike-slip fault zones, with a component of left-slip or oblique-faults at the subject site. Antithetic faults typically are minor compared to the primary faults along the principal displacement zone (PDZ) where most of the fault slip occurs, but secondary faults may move during large earthquakes in addition to the primary faults.

Conclusions

Seismic reflection profiles obtained across the WBHL in the vicinity of the subject site confirm the complex pattern of faulting in cross-section, although the data are inadequate to clearly show downward-convergent faulting (flower structure). The CPT profiles and some boreholes provide confirmation of the complex fault pattern, too. Unfortunately, the few seismic profiles and geological transects in the vicinity of the subject site are insufficient to provide accurate mapping of the fault surface traces or shallow subsurface traces in three dimensions.

More detailed interpretation of this stratigraphic sequence cannot be attempted at this time without further data, but the primary observation that this surface is warped into the monocline and offset by shallow faults in the zone along the WBHL is significant. Terminations of high-frequency shallow reflections are apparent and may indicate near surface fault offset. However, due to the poorer image quality at the shallowest levels below the ground surface, it cannot be conclusively demonstrated that the faulting reaches the ground surface or offsets young alluvial layers that may be Holocene in age. The lack of obvious reflection terminations or offsets to the east of about 2400-ft is consistent with absence of significant shallow faulting in this area. Geological ground truth, by excavation or borehole drilling, is necessary to conclusively identify near-surface faulting of Holocene age associated with active fault traces.

Additional Investigation Alternatives

To more accurately define the fault pattern in three-dimensions across the subject site, additional seismic profiles, fault trenching, boreholes, or other subsurface investigations are required. With limited accessibility, due to existing construction, only a few locations exist where two- and three-dimensional subsurface investigations may be attempted. Three-dimensional investigations that may be applied include 3-D seismic profiling and 3-D fault trenching investigations. The former technique is less destructive with minimal disruption of the ground whereas the latter results in the ultimate destruction of the shallow geologic record, but with thorough documentation during the excavation can provide a higher resolution mapping of the shallow structure. Geological sampling is always necessary to confirm interpretations derived from geophysical and other remote sensing data.

Three-dimensional (3-D) seismic profiling is used to great extent by the petroleum industry because the complex nature of the real earth seldom can be approximated by 2-D cross-sections. Lateral as well as vertical variability of subsurface geological structure is significant, especially along strike-slip fault zones. Use of 3-D seismic imaging technology provides a non-destructive way of imaging the complex subsurface geological structure and stratigraphy. The costs of 3-D seismic imaging are significantly greater than 2-D methods, but for land data, there are some techniques that can be used to reduce these costs substantially. The trade-offs that must be addressed involve subsurface resolution and depth of imaging versus cost of effort in acquisition and data processing. In particular, deeper imaging requires a wider area of surface data acquisition, or use of expensive subsurface geophones (borehole arrays) in order to accurately image deeper subsurface stratigraphic horizons and faults. For assessing ground surface deformation at the subject site, it may be reasonable to focus on only the upper few tens of meters (hundreds of feet) for the seismic imaging. It is desirable to image at least to the strong reflector identified in the existing 2D seismic profiles – the unsaturated sand layer between saturated clays as interpreted by GeoVision in Appendix D of the Century City Area Fault Investigation Report. This reduces the scope and cost of such efforts.

Possible 3-D subsurface seismic imaging techniques that may be applied at the subject site include: 1) surface array acquisition (conventional) using P-wave or S-wave (multicomponent), 2) subsurface array acquisition (borehole arrays), or combinations of these two basic methods. An open area that covers the fault zone with sufficient extent beyond the fault zone is needed for surface methods to allow migration of seismic energy scattered away from the faults back into the image area (aperture considerations). A minimal 3-D survey could be a narrow swath, oriented perpendicular to the major structure of interest (WBHL); at least a more accurate determination of fault dip and strike could be obtained with a swath survey. The swath width must be sufficient to capture seismic energy scattered to the sides (side-swipe) for migration into (or out of) the image volume. For subsurface methods, existing well or borehole locations may be occupied or new boreholes drilled to install source and receiver arrays.

Other 3-D geophysical imaging methods may be relevant, such as ground-penetrating radar (GPR), to provide accurate images of the complex fault pattern (and possible paleo-stream channel patterns). GPR has high-resolution but limited penetration imaging of the subsurface. Also, GPR may suffer from electromagnetic interference in highly urbanized areas. Other electrical or magnetic imaging methods are available, but lack the resolution for imaging shallow faulting provided by seismic reflection profiling or GPR.

Primary target zones for 3-D imaging or mapping of surface deformation include:1) zones of faulting inferred from disruption of subsurface reflectors in the P-wave and S-wave seismic reflection profiles and the CPT/borehole transects (WBHL); 2) area of monoclinal flexure associated with the WBHL and southwest corner of the Hollywood Basin.

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List of Figures

APPENDIX

Data Acquisition and Processing Notes

Transect	Observation	Interpretation and Problems
All	long offsets used for deeper penetration	smear shallow reflection events, mute used to remove NMO stretch
All	f-x process to smooth data	more coherent for interpretation, but smears data and may obscure minor fault offsets
All	migrated seismic profiles show sharper image of structure	complex shallow velocity field may create artifacts due to velocity changes rather than actual geological structure
P-Wave	datum = 340' elevation; line 2 datum = 325' elevation, lines 4, 7	replacement velocity = 6,000 ft/sec; all lines
Seismic Interpretation Notes		
#2-2E	strong reflection event(s) @ 120-140 ms twtt; depth = 150' to 300' subsurface	Pleistocene terrace surface? (Similar to HB Warner Ave); correlates with top of San Pedro Fm (T2E-B3,T2-B4,B6,B8)
T2-B4 P-S Suspension Logs	157'-172' low velocity (P-Wave) 177'-182' low velocity (P-Wave)	unsaturated coarse-grained sand (San Pedro Fm) capped by saturated clays? (Paleosol?) corresponds to strong reflection event; clay caps may be paleosols on erosional terrace surface, beach sands, or nearshore sand bar
T2E-B3 P-S Suspension Logs	175'-200'+ low velocity (P-Wave)	unsaturated sand layer with elevated S-Wave velocity (high S-Wave velocity = coarse-grained; San Pedro FM)
#4	strong reflection event(s) @ 100-140 ms twtt; depth = 170'-300'	Pleistocene terrace surface?
#4	S-Wave reflector @ 250 ms and 400 ms twtt; depth = 140' and 235'(?)	corresponds to P-Wave reflector (100-140 ms twtt); Pleistocene terrace surface?
#4	S-Wave data incoherent - Stn 220' to 300'	zone of faulting
Other Seismic Hazards		
#2E & #4	saturated sands to east	liquefaction potential

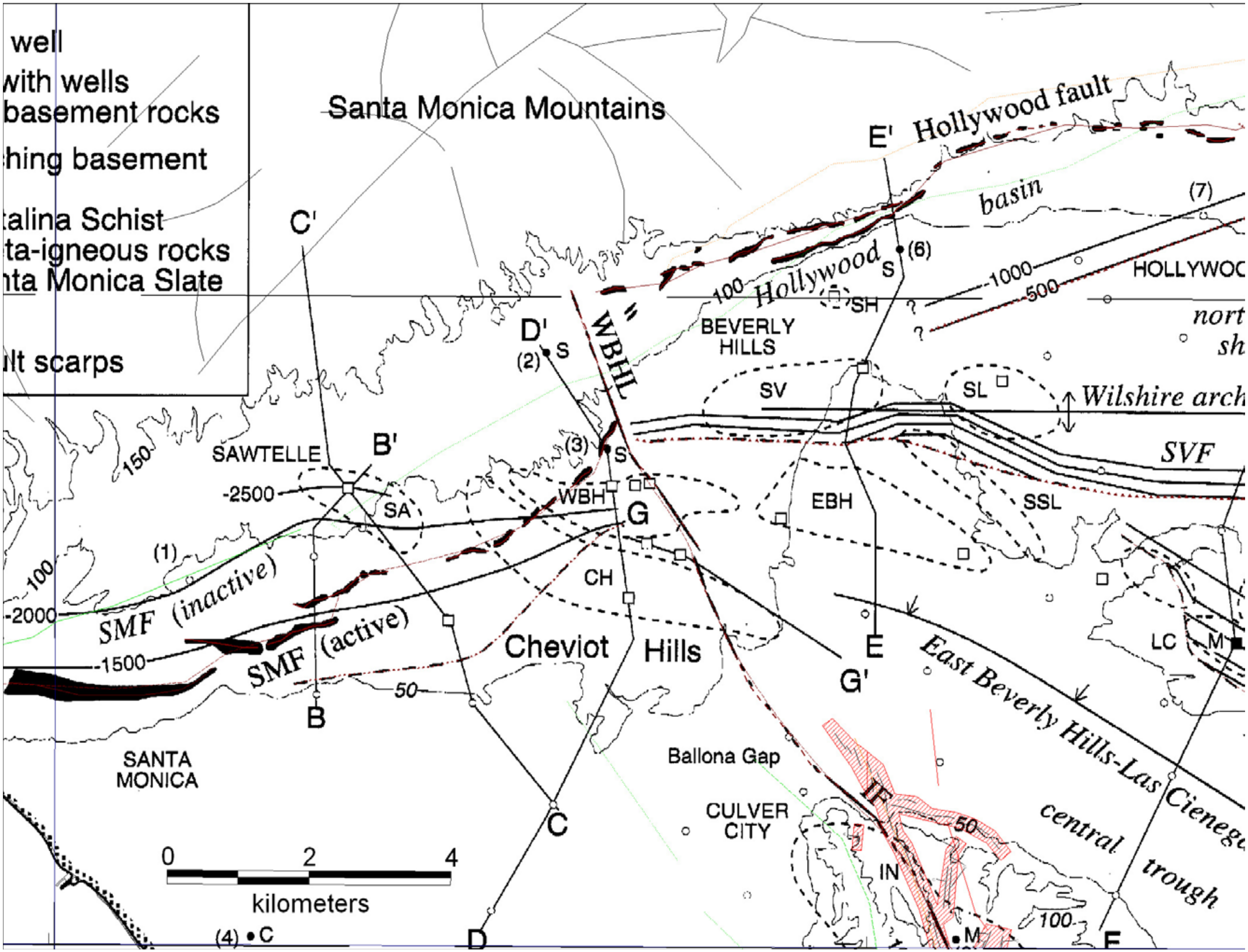

well
with wells
basement rocks
hing basement
alina Schist
ta-igneous rocks
nta Monica Slate
lt scarps
Santa Monica Mountains
Hollywood fault
E'
basin
(7)
(6)
S
Hollywood
100
SH
HOLLYWOO
-1000
-500
nort
sh
BEVERLY
HILLS
D'
(2)
WBHL
C'
SV
SL
Wilshire arch
SVF
SAWTELLE
B'
150
(3)
-2500
SA
WBH
G
EBH
SSL
(1)
100
-2000
SMF (inactive)
CH
LC
M
SMF (active)
-1500
Cheviot
Hills
E
G'
East Beverly Hills-Las Cienega
50
B
SANTA
MONICA
Ballona Gap
CULVER
CITY
IF
50
central
trough
C
IN
0
2
4
kilometers
(4)
D
100
M
F

Figure 1

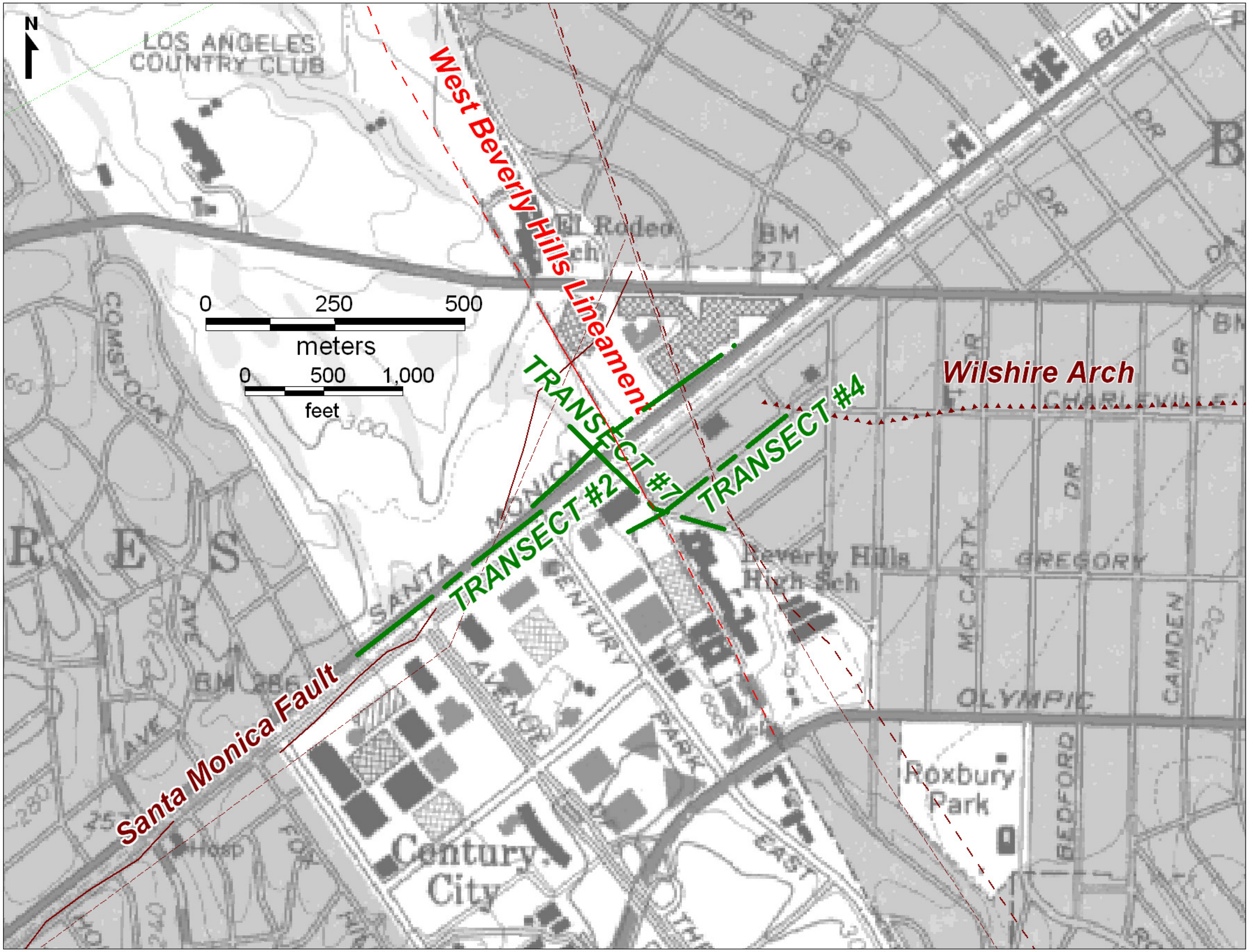

N
LOS ANGELES
COUNTRY CLUB
West Beverly Hills Lineament
0
250
500
meters
0
500
1,000
feet
TRANSECT #7
TRANSECT #2
TRANSECT #4
Wilshire Arch
Santa Monica Fault
El Rodeo
Sch
Beverly Hills
High Sch
Century
City
Roxbury
Park
OLYMPIC
GREGORY
CHARLEVILLE
MC CARTY
CAMDEN
BEDFORD
COMSTOCK
SANTA MONICA
CENTURY
AVENUE
PARK
EAST
CARMELITA
BLVD
BM
271
R E S

Figure 2

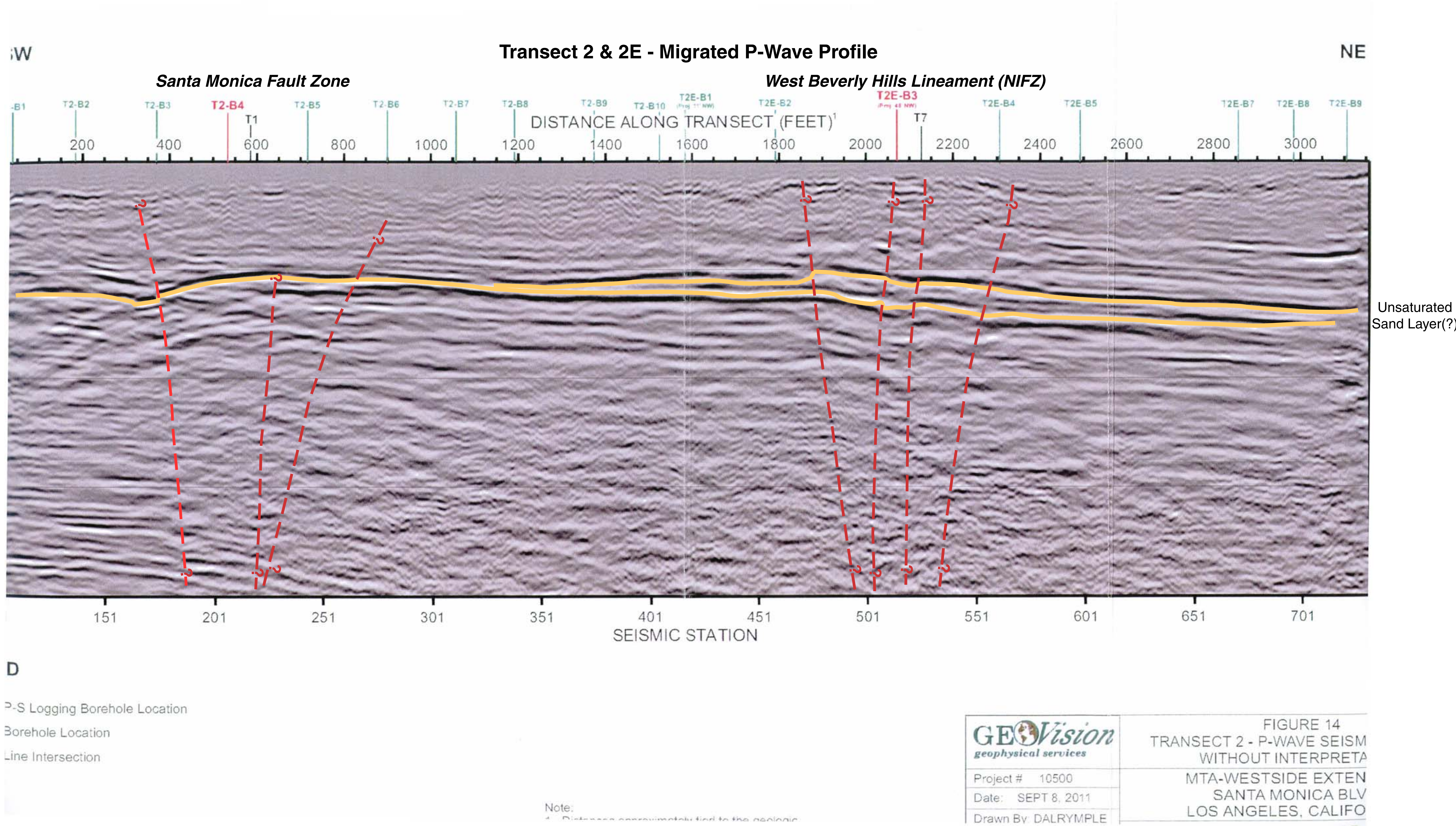

SW
Transect 2 & 2E - Migrated P-Wave Profile
NE
Santa Monica Fault Zone
West Beverly Hills Lineament (NIFZ)
T2-B2
T2-B3
T2-B4
T1
T2-B5
T2-B6
T2-B7
T2-B8
T2-B9
T2-B10
T2E-B1
T2E-B2
T2E-B3
T7
T2E-B4
T2E-B5
T2E-B7
T2E-B8
T2E-B9
DISTANCE ALONG TRANSECT (FEET)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Unsaturated
Sand Layer(?)
151
201
251
301
351
401
451
501
551
601
651
701
SEISMIC STATION
P-S Logging Borehole Location
Borehole Location
Line Intersection
Note:
GEOVision geophysical services
Project # 10500
Date: SEPT 8, 2011
Drawn By: DALRYMPLE
FIGURE 14
TRANSECT 2 - P-WAVE SEISM
WITHOUT INTERPRETA
MTA-WESTSIDE EXTEN
SANTA MONICA BLV
LOS ANGELES, CALIFO

Figure 3

Transect 4 - Migrated P-Wave Profile

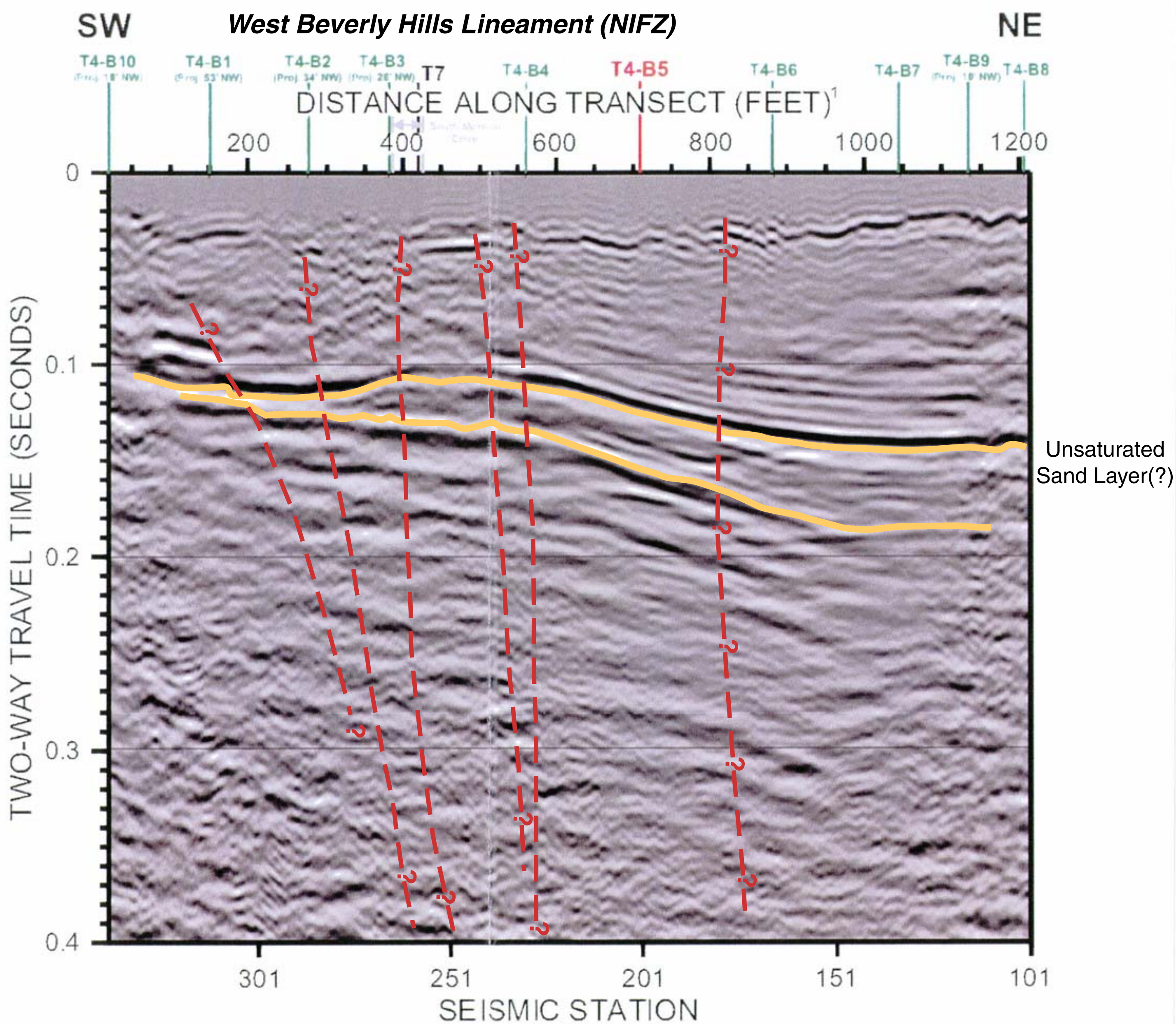


Figure 4

Transect 4 - Migrated S-Wave Profile

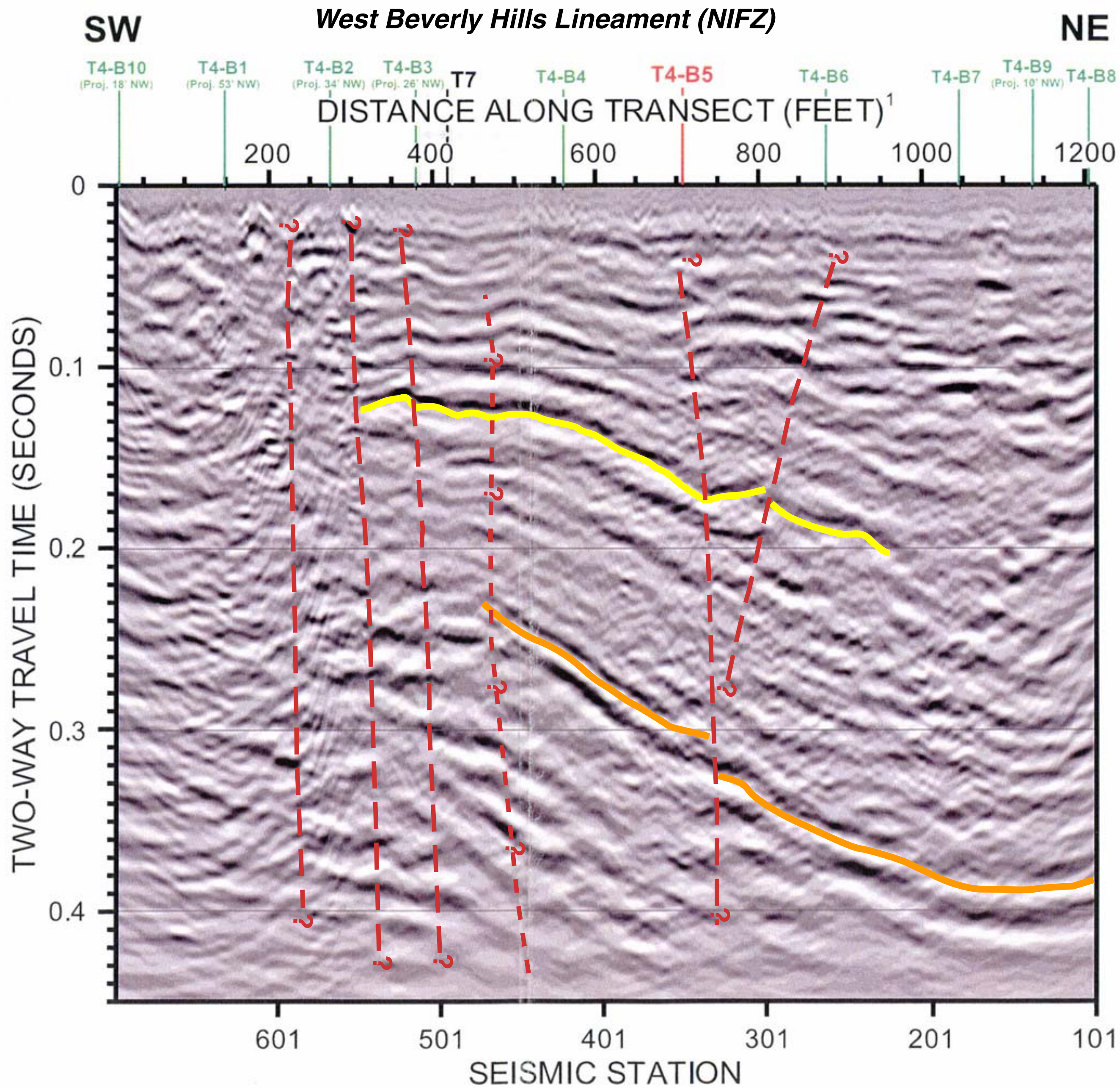


Figure 5

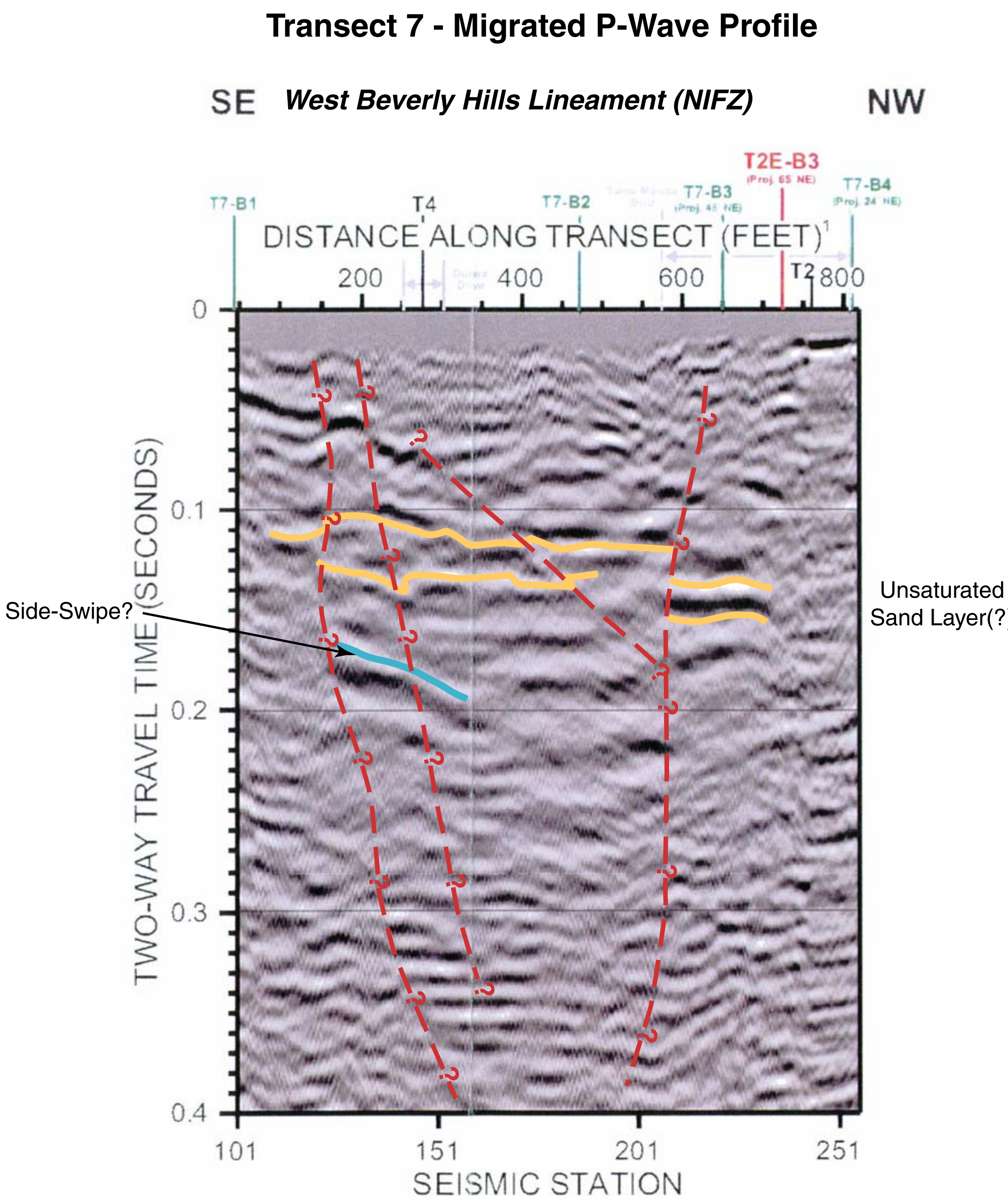

Transect 7 - Migrated P-Wave Profile
SE
West Beverly Hills Lineament (NIFZ)
NW
T2E-B3
T7-B1
T4
T7-B2
T7-B3
T7-B4
DISTANCE ALONG TRANSECT (FEET)
200
400
600
T2
800
0
0.1
0.2
0.3
0.4
TWO-WAY TRAVEL TIME (SECONDS)
Side-Swipe?
Unsaturated
Sand Layer(?)
101
151
201
251
SEISMIC STATION

Figure 6

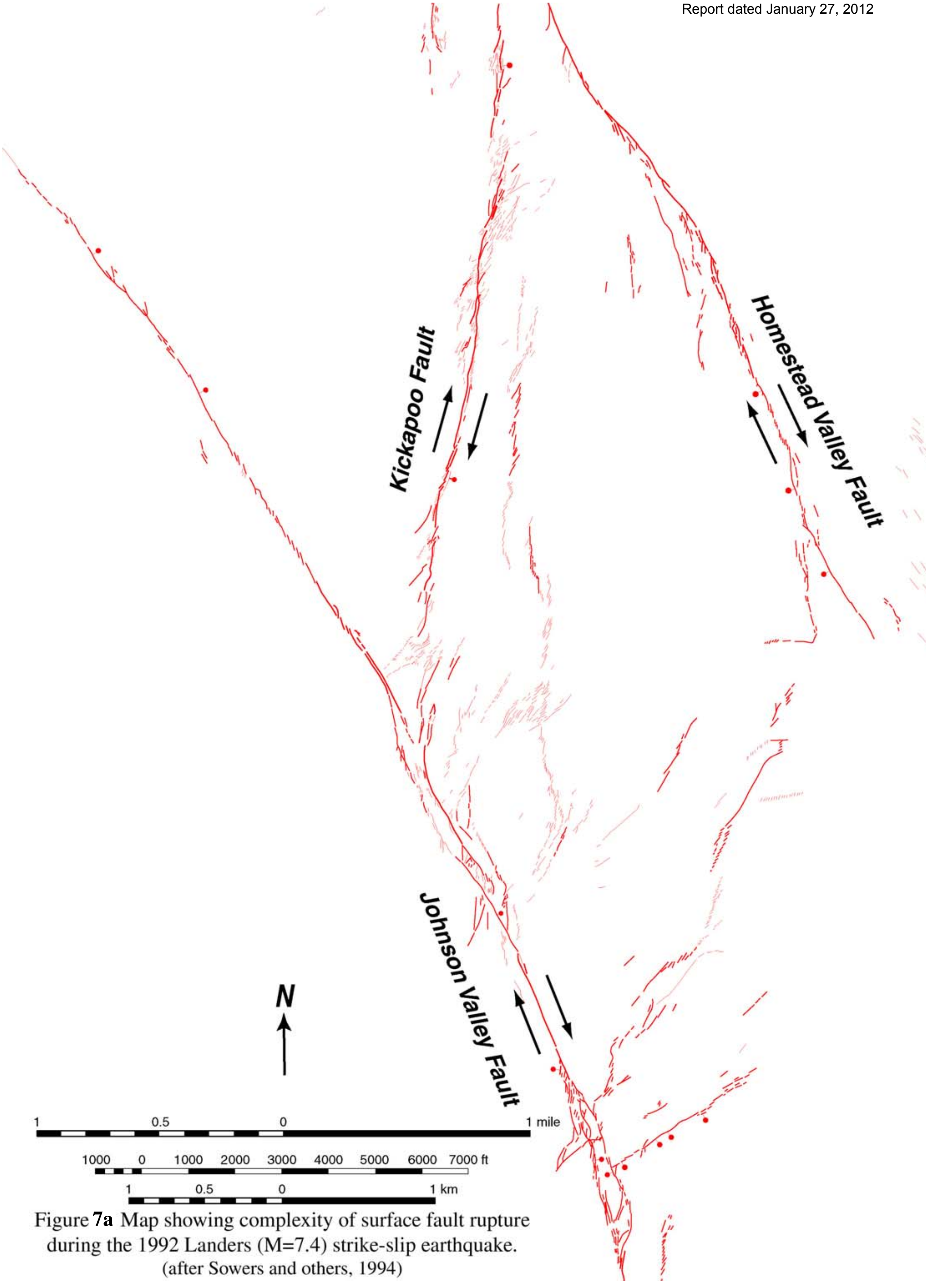


Figure **7a** Map showing complexity of surface fault rupture during the 1992 Landers (M=7.4) strike-slip earthquake. (after Sowers and others, 1994)

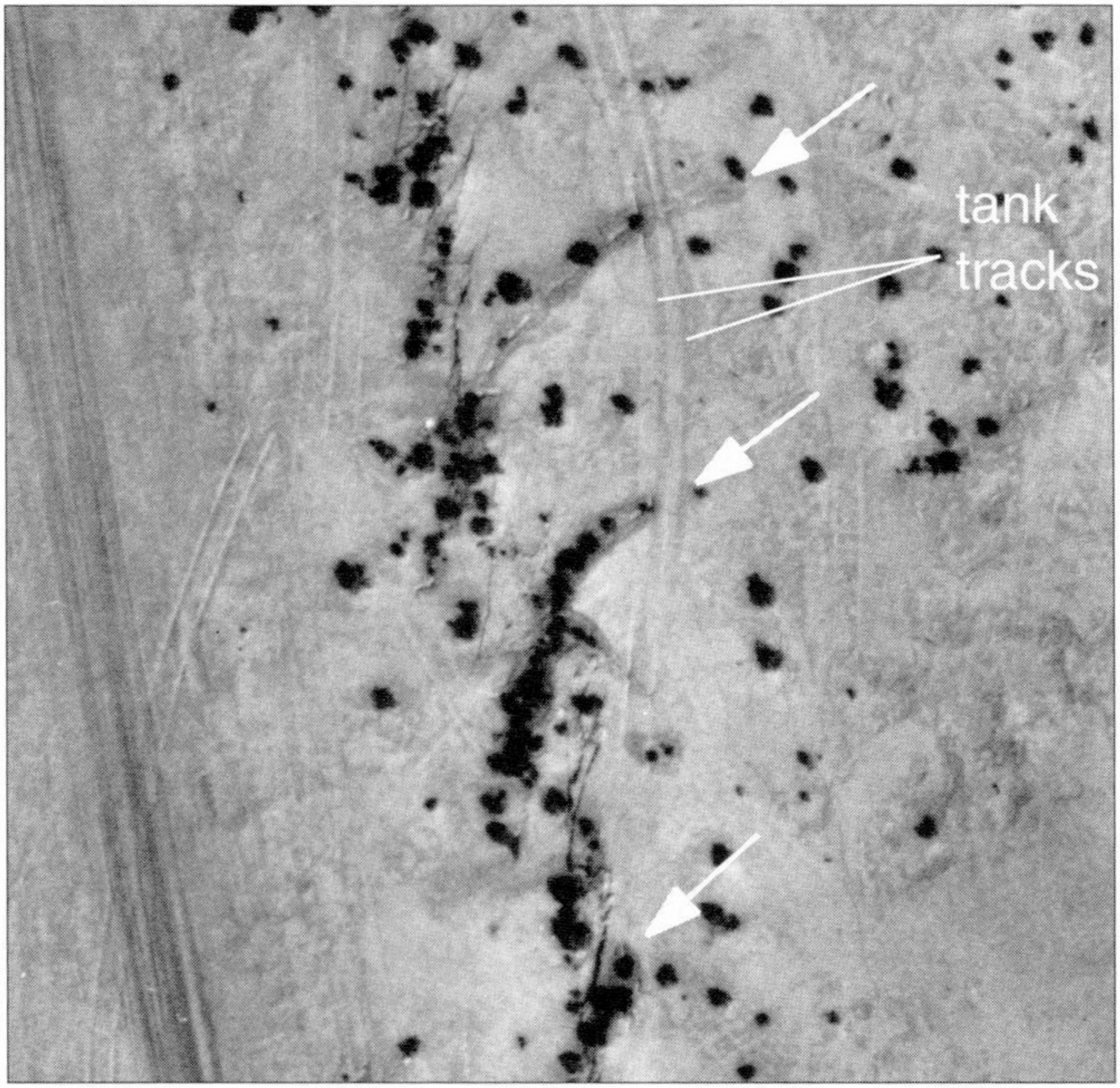


Figure 7b. North-trending splay of the Lavic Lake fault (kilometer 7) with minor rupture along a series of pre-existing, left-stepping, en echelon shears that are accentuated by vegetation lineaments and linear rills (arrows). Tank tracks are approximately 2.5 m wide; north is toward the top of photo (photo by I. K. Curtis, portion of frame 8–14).

(Source: Treiman et al. 2002)

Beverly Hills High School

<u>Independent Review of</u>

<u>Metro Century City Area Fault Investigation Report Appendix D</u>

Mark R. Legg, PhD, PG, RGP, Legg Geophysical, Inc.

INTRODUCTION

This report presents an independent review of Appendix D of the Century City Area Fault Investigation Report (CCAFIR) prepared for Metro as it relates to the Beverly Hills High School (BHHS). The evaluation is based on geological and geophysical data documented in the CCAFIR for the Los Angeles Westside Subway Extension Project and other published information relevant to faulting located in the vicinity of the subject site. Appendix D, titled "High Resolution Seismic Reflection Survey" was prepared by GEOVision for AMEC Environment & Infrastructure (AMEC). The following is an update to the previous report and adds more detailed interpretation of the two SE-NW trending seismic profiles located west of the Beverly Hills High School site. These profiles are important for understanding the location and character of the Santa Monica Fault (Zone), which has been mapped to the north of the school and appears to terminate along the West Beverly Hills Lineament (WBHL).

INTERPRETATION OF SEISMIC PROFILES

The seismic interpretation focuses on the migrated P-wave profiles, which show some coherent reflection horizons (reflectors) that allow identification of shallow faulting. The S-wave profiles along Transect #1 & 8 and Transect #3 suffer from serious background noise in this urban setting and lack good coherent reflectors that could be correlated to the boreholes along the geological profiles.

AMEC Transect #1 & 8 (Figure ?)

Transect 1-8 provides an excellent example to demonstrate the fact that: "Seismic Profiles are NOT Geologic Cross-Sections" – seismic velocity structure must be known to convert time (two-way travel time = twtt) to depth (and vice versa). P-wave seismic velocities are relatively constant and high, around 5000-6000 fps below the groundwater interface, but very low and highly variable at shallow depths where water saturation varies. Where velocity structure is measured, e.g. at T2-B4 and T1-B6, borehole picks of the top of stratigraphic horizons can be located along the profile. Where velocity soundings are unavailable, we must assume velocity structure using what data are available. Approximate twtt for the horizon tops of the Lakewood Formation (Qlw) and San Pedro Formation (Qsp) are shown based on the available velocity information. A slow average velocity (1400-1900 fps) was used for these horizons where they lie at or above the groundwater measured in the boreholes. This assumption appears reasonable because the horizon picks are located near the strong (bright) reflection horizon that correlates with the San Pedro Formation. Two major course changes (C/C) along the profile may also confuse interpretation of the seismic data by distorting the apparent dip of subsurface structure. As stated in the GeoVision (2011) report, the seismic profiles were processed for fault interpretations and not stratigraphic mapping, which would require the more detailed velocity analysis and time-to-depth conversion.

The migrated P-Wave profile shows some coherent reflections including the shallow unsaturated sand layer (bright reflector) at about 0.1-sec twtt, which correlates to the San Pedro Formation (Qsp) identified in the borehole logs. This layer is shallow at the southeast end of the profile (depth about 65-ft to 83-ft), deepens toward and within the Santa Monica Fault Zone (depth about 106-ft to 148-ft) and shallows again at the north end of the profile. Seismic velocity effects delay reflection arrivals from this layer to later twtt (velocity pull-down) at the southeast end so that it appears to be a relatively level horizon across the seismic profile. Based on the borehole data, Qsp deepens from elevation 235-ft to 185-ft (SE to NW deepening of about 50 feet) as far north as the major fault at T1-B8 (location 1240-ft). The elevation of Qsp varies significantly on the northwest end of the profile where it is offset by multiple fault traces in the Santa Monica Fault Zone and ultimately rises to about elevation 222-ft at T1-B7 (location 2190-ft). Deeper layers are less continuous across the profile than Qsp and cannot be correlated to the shallow boreholes, but provide useful information on the character of deeper structure.

Fault interpretations are consistent with the GeoVision (2011) interpretations, in general, although there are a few significant differences. First, we interpret the main trace of the Santa Monica Fault (north branch of Tsutsumi et al. 2001) to be the fault(s) identified in the near surface between boreholes T1-B8 and T1-B3 – with sheared clay over silt at 164-ft depth (elevation 136-ft), minor fault with 60-70 degrees dip at 153-ft depth (elevation 147-ft), and sheared clay zones at 153-ft to 156-ft depths (elevations 144-ft to 147-ft). At least two significant faults are interpreted to converge in the vicinity of borehole T1-B8 (location 1240-ft) where a poor recovery zone was identified at about 70-ft depth (elevation 228-ft to 237-ft). GeoVision (2011) interpreted the most significant fault to be vertical at this location. Although a possible vertical fault may be inferred slightly south of the GeoVision interpretation, we interpret the main faults in the zone to be north-dipping. Deeper coherent reflections at about 0.30-sec to 0.37-sec (twtt) appear to be terminated near location 1400-ft and offset near location 1600-ft.

Tying seismic reflections to the boreholes along Transect #1 shows the relative vertical separation of the Quaternary San Pedro Formation across the different branches of the Santa Monica Fault. Normal separation of about 57-ft is implied between boreholes T1-B8 and T1-B3, where the "strongest structure" is shown on the geological cross-section (AMEC, 2011). Upwarp in the hanging wall of this fault appears to represent reverse drag, possibly related to structural inversion of an ancient normal fault by subsequent contraction and reverse-slip. The inferred fault that approaches the ground surface near location 1600-ft is in the zone of limited geological data. However, vertical separation of about 40-ft is implied by elevations of the San Pedro Formation between boreholes T2-B4 and T1-B6. Reverse separation is interpreted on the faults to the north near locations 1450-ft and 1750-ft along the geological transect, and recognized in the seismic profile across faults near T1-B5 and T1-B7 (locations 1790-ft and 2150-ft). An additional vertical separation of about 50-ft is implied between T1-B6 and T1-B7 near the north end of the transect. The latter appears to exist as reverse slip on the fault that intersects T1-B6 near location 2000-ft, but the seismic data show the major fault offset on the near vertical trace near location 2080-ft. These two fault traces appear to represent flower structure on a major downward-steepening fault. San Pedro Formation rises to elevation 222-ft at T1-B7 near the end of the profile, still 13 feet lower than at the south end of the profile (elevation 235-ft).

Lateral variation in seismic velocity structure complicates the seismic interpretation. Higher velocities to the north measured at borehole T1-B6 (location 1790-ft) result in greater depths to the bright reflection (Qsp) than implied by the average velocity structure, perhaps as much as 40-ft deeper. In the footwall beneath the fault near T1-B5, the overthrust Qsp horizon appears to flatten, suggestive of a velocity pull-up effect – reverse separation on a deeper reflector across a questionable fault may be enhanced by the velocity pull-up effect. Note that the transect bends to the northeast at Santa Monica Boulevard, from about 1570-ft to 1670-ft, ending close to the truncation of the overthrust Qsp horizon, which may further complicate this interpretation. The complex pattern of faulting, with alternating reverse and normal separation may represent flower structure in a strike-slip fault zone. South dip of Qsp and other horizons identified in the geological transect may result from additional reverse faulting to the north, possibly the Benedict Canyon Fault, associated with uplift of the Santa Monica Mountains.

AMEC Transect #3 (Figure ?)

The P-wave seismic profile along Transect #3 is relatively short (~1250-ft) and crosses the southern part of the Santa Monica Fault Zone. The geological profile continues farther to the northwest (length ~1720-ft) beyond Santa Monica Boulevard. Only one borehole (T3-B3, location ~550-ft) with velocity measurements exists along this profile, but the southern 80% of line appears relatively uniform – the shallow reflectors are roughly horizontal. Several strong (bright) and coherent reflectors are identified – the most prominent at about 0.08-s twtt correlates to the San Pedro Formation (Qsp) based on the boreholes along the central part of the profile. Shingling of this horizon apparent between 500-ft and 800-ft may be due to depositional processes but faulting disrupts the surface in other places.

At the SE end of the profile, south of location 300-ft, the Qsp reflector is subdued but still apparent and shown as a dotted line in the interpretation. Weaker reflectivity and vertical oscillations may represent a separate fault block with different velocity structure and shallow dispersion of seismic energy, or a channel with artificial fill to location 500-ft; the 300-ft location is approximately where the silty-sand facies of the Lakewood Formation pinches out in the geological profile leaving the more coarse-grained poorly graded sand unit in contact with older alluvial fan deposits. Coarse-grained deposits (gravel, channel deposits?) in these sequences may scatter the seismic energy here. The upwarp of Qlw and Qsp horizons combined with subtle reflector terminations and offsets at depth may indicate faulting, too.

At the north end of the line, in the complex area of reflectivity associated with the Santa Monica Fault Zone, the Qsp reflector is identified (dotted line) south of the main fault trace, but has not been identified farther north on the seismic profile – the borehole data (T3-B7) did not reach the Qsp strata here. Farther north, borehole SB-1 (location ~1640-ft) found the Qsp layer at about 117-ft depth (elevation 186-ft).

The Lakewood Formation was identified in most of the boreholes – a high-frequency continuous reflector at about 0.04-s twtt correlates to this horizon. This reflector is also subdued at the south end of the profile and disrupted at the north end where the Santa Monica Fault Zone exists. Borehole T3-B7 did not identify the Lakewood Formation (deeper than borehole or not recognized?). Shallow groundwater levels (about 23-ft depth at T3-B6, location 1020-ft) may account for the coherent reflectors offset by multiple faults at the north end (beyond 1000-ft), and higher velocities at shallow depths would force these events to appear shallower than equivalent horizons south of the fault zone where groundwater is deeper (> 60-ft depths).

Fault interpretations are consistent with the GeoVision (2011) interpretations but include more faults that represent a complex zone of deformation. The major fault (zone) at northwest end of the profile (locations 900-ft to 1020-ft) appears to be a near vertical fault with shallow flower structure. Normal separation, vertical drop of about 50-ft across north-dipping faults south of the main fault, are similar to offsets observed in Transect #1-8. Combined with reverse separation to the north of the profile, a narrow graben in a possible flower structure is identified – consistent with a strike-slip fault zone. In the geological profile, the near vertical fault at T3-B6 (location 1020-ft) shows normal separation across multiple faults (and a small popup, reverse separation, at the southern flank) seismic resembles structure, too. Horizon Qlw is recognized at elevation 252.5-ft at T3-B5 (location 860-ft and at elevation 200-ft at T3-B6 across the main fault zone; Qsp is recognized at elevation 203-ft at T3-B2 (location 400-ft) and at elevation 176-ft at T3-B6 (location 1020-ft). About 50-ft of vertical separation is measured for Qlw, but only about half that amount for the older Qsp horizon. The Lakewood Formation section is 25-30 feet thinner in the graben than to the south of the fault, and Marker Beds D and G are missing in the fault zone. Inconsistent stratigraphic correlations across faults is typical for strike-slip faults.

The geological profile continues farther north than the seismic and identifies Qsp at elevation 186' at borehole SB-1 (location 1640-ft) across an inferred fault at location 1300-ft to 1400-ft. As observed on Transect #1-8, reverse separation to the north bounds a narrow graben along the Santa Monica Fault Zone in this area. The graben identified in the seismic profile is poorly defined at northwest end due to lack of stratigraphic control and termination of the line south of the reverse-separation fault(s). Boreholes and CPTs between T3-B6 and SB-1 are too shallow to reach Qsp or Qlw according to the geological interpretations. Borehole G-159 (location 1260-ft) reaches a depth of 121-ft (elevation 154.5-ft) without identifying Lakewood (Qlw) or San Pedro (Qsp) Formations. More than 30-ft of vertical separation (Qsp and possibly 45-ft for Qlw) must be accommodated by the reverse fault(s) north of the seismic profile. San Pedro Formation (Qsp) remains 20-ft lower at the north end of the geological profile than at the south end – south dip and additional reverse-faults to the north presumably accommodate uplift above the main Santa Monica Moutains Thrust.

Other faults south of the main Santa Monica Fault Zone are interpreted at reflector terminations. The interpretation strategy is to recognize larger stratigraphic trends, terminations, deflections and offsets as possible fault traces. Some of these (the south dipping fault between locations 500-ft and 800-ft) may be axial surfaces for deeper contractional structures. A low-angle thrust, possibly a branch of the Santa Monica Fault South Strand, is inferred to terminate (offset?) deeper horizons (orange event). Other minor(?) high-angle faults also appear to offset these reflectors, but stratigraphic control to identify the horizon is unavailable at this time. This rollover anticline of deeper stratigraphic horizons is consistent with a blind thrust fault. Strain partitioning between deep oblique(?) thrust faulting and shallow strike-slip (oblique-reverse?) faulting appears consistent with complex fault pattern and flower structure on the major fault at T3-B6 (location 1020-ft).

Conclusions

The seismic data and the geological transect together suggest that the major reverse fault traces exist north of Santa Monica Boulevard, beneath the Los Angeles Country Club, whereas the other major active fault traces south of the boulevard show normal separation, down-to-the-north. Normal separation across the fault(s) near T1-B3 (location 1300-ft) in the seismic profile appears inconsistent with a major reverse fault – the north side (hanging wall) of the fault is relatively down-thrown. The AMEC (2011) geological interpretation of the main fault located near 1240-ft on Transect #1-8 shows normal separation of the San Pedro Formation, consistent with the seismic interpretation. However, cross-section D from Tsutsumi et al. (2001) located between Transect #1 and Transect #7 shows reverse separation in the shallow subsurface where the historic topographic escarpment existed (Dolan and Sieh, 1992). The Tsutsumi (2001) cross-section does not show the complexity of faulting in this area evident in the recent borehole, CPT, and seismic profiles. A narrow graben along the fault zone exists at the Qsp horizon between the faults at T1-B8 and at T1-B5 (locations 1240-ft to 1790-ft). This coincides with the area of the topographic scarp that was inferred by Dolan and Sieh (1992) to represent a reverse fault. The graben identified in the subsurface data implies that the topographic feature represents a fault-line scarp resulting from differential erosion (and deposition within the graben) controlled by the broader Santa Monica Fault Zone in this area. Fault activity, specifically Holocene displacement remains to be confirmed, although significant Quaternary displacement is demonstrated by the offset horizons in the borehole and CPT profile. An alternative interpretation is that older normal faults have been reactivated as reverse faults and structural inversion has superseded graben formation. The former topographic scarp and older alluvial fan sequences mapped in the geological profile may support this hypothesis, but more detailed investigation may be required. A third alternative, which may be relevant in any case, is that a component of strike-slip has juxtaposed differing thicknesses of strata across the fault.

<u>Summary</u>

1. Santa Monica Fault – main trace is north-dipping at about 1240-ft on Transect #1-8 and consists of possibly two traces, although a vertical fault may be present at depth. This may represent flower structure. The main fault appears sub-vertical on Transect #3 and more closely resembles flower structure, but the seismic profile ends south of the Santa Monica Boulevard and does not cross the entire zone of faulting.

2. Bright reflection horizon (unsaturated sand?) is correlated to the top of the San Pedro Formation (Qsp) and appears to show reverse drag on Transect #1-8. Velocity effects and course changes on the seismic profile must be considered to produce an accurate depth cross-section.

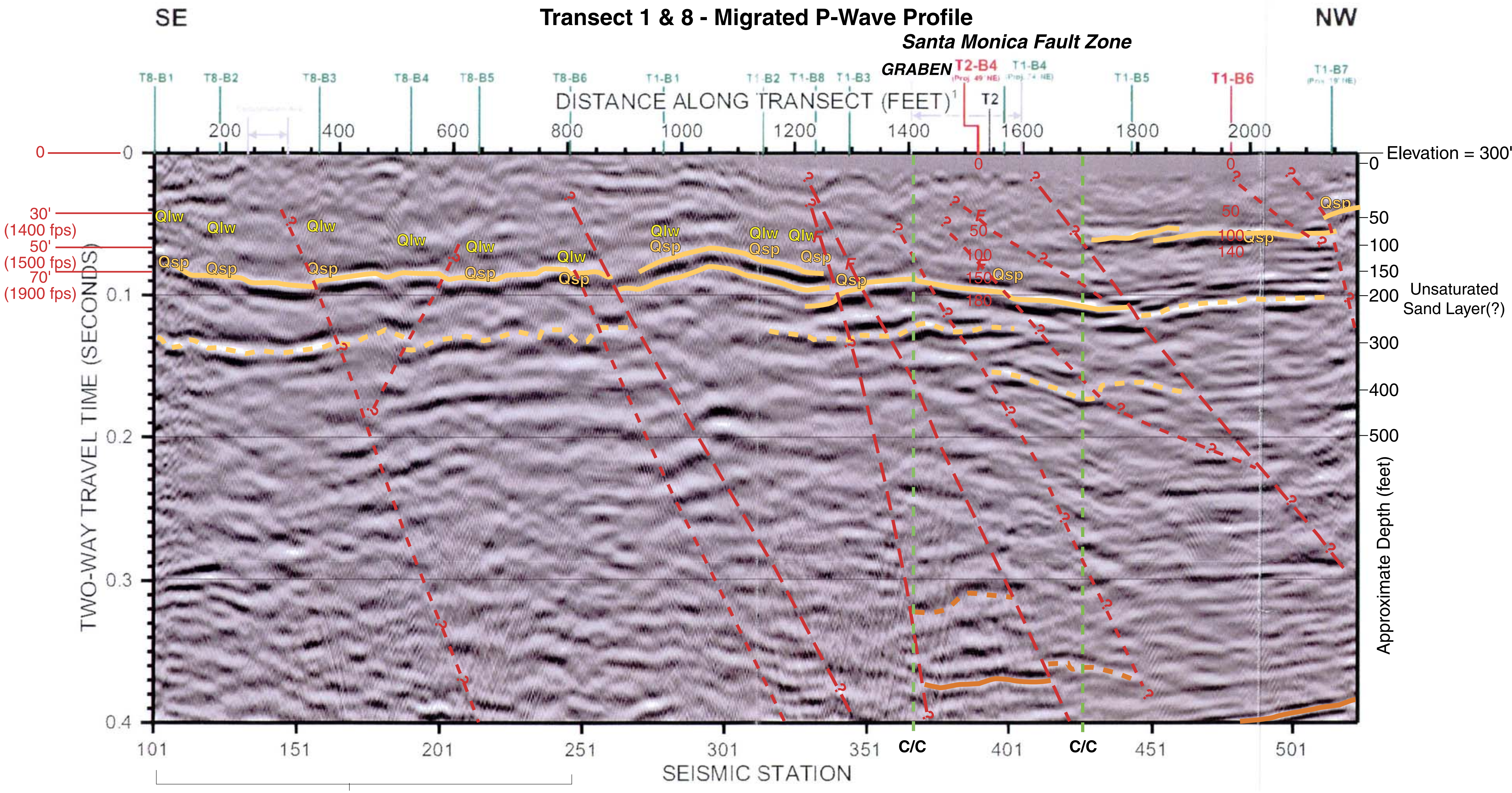
3. A graben exists between major fault traces of the Santa Monica Fault Zone with the major reverse separation apparent on the northern fault strands near the end of the transects. The graben appears to be located where the “active fault scarp” was interpreted by Dolan and Sieh (1992). The graben is located south of Santa Monica Boulevard on Transect #3, which also coincides with the former topographic scarp. Strata north of the graben exhibit south dip, which may represent rollover structure or down-tilting of the block north of the Santa Monica Fault active traces. There may be additional faults, possibly with reverse-separation, located farther north such as the Benedict Canyon Fault.

4. Within the graben, the shallower Lakewood Formation (Qlw) appears to show greater normal separation (about 50-ft) than the San Pedro Formation (Qsp, less than 25-ft?) on Transect #3 and is thinner (absent on Transect #1-8). Did the graben form during deposition of Qlw, and did subsequent reverse displacement elevate and remove this unit? It does not exist north of the Santa Monica Fault Zone? Significant strike-slip displacement may have juxtaposed variable thicknesses of these sequences across the fault in this area. Reverse separation in shallower sequences may represent late Quaternary oblique-reverse faulting and possibly

incipient structural inversion of the graben. This process could explain the former topographic scarps along the fault above the graben. The Pleistocene graben is not recognized on published cross-sections in this area Wright, 1991; Tsutsumi et al. 2001).

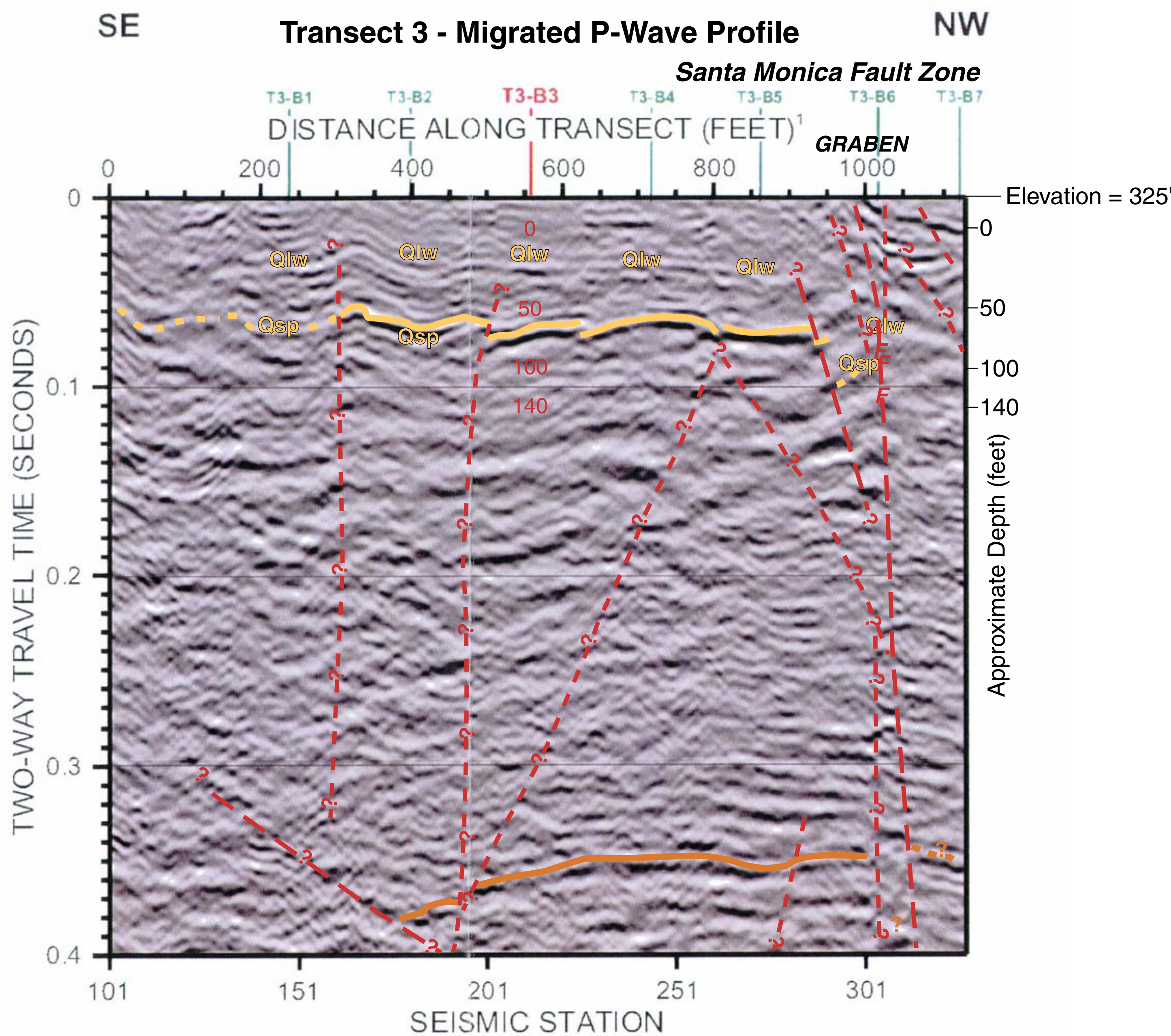
5. Compared to Transect #3, which shows a steeper and narrower fault zone in the seismic profile, horsetail splays near the termination of the Santa Monica Fault likely accounts for the complex fault pattern observed on Transect #1-8. This fault character is typical of strike-slip fault termination and consistent with a termination bulge at the edge of a major releasing stepover or pull-apart basin. Transect #3 shows additional fault splays north of the seismic profile.

Report dated May 10, 2012



Qlw Depth based on velocity of 1400 fps (above shallow groundwater) SE of T8-B8

Qsp Depth based on velocity of 1900 fps (above shallow groundwater) SE of T8-B8


SE
Transect 3 - Migrated P-Wave Profile
NW
Santa Monica Fault Zone
T3-B1
T3-B2
T3-B3
T3-B4
T3-B5
T3-B6
T3-B7
DISTANCE ALONG TRANSECT (FEET)[1]
GRABEN
0
200
400
600
800
1000
Elevation = 325'
Qlw
Qsp
TWO-WAY TRAVEL TIME (SECONDS)
0
0.1
0.2
0.3
0.4
Approximate Depth (feet)
0
50
100
140
101
151
201
251
301
SEISMIC STATION

Notes:

Stratigraphy

1. bright reflector appears to correlate with the top of the San Pedro Formation (Qsp); borehole data are crucial to proper interpretation of the seismic; lack of velocity data at SE end of profile makes location of borehole horizon picks uncertain – formation picks appear too shallow if bright reflector is Qsp [Note: significant difference in twtt to depth conversion for the two velocity profiles at T2-B4 and T1-B6] [Note2: seismic data were processed for fault interpretation, not stratigraphic interpretation – shallow velocity structure not evaluated in detail for time to depth conversion][Note3: groundwater level near top of Qsp or Qlw for SE end of profile – velocity in unsaturated shallow layers is very slow ~1300-1900 fps at borehole T2-B4 – so bright reflector may be Qsp][Note4: groundwater shallows between T8-B6 and T1-B1 – fault inferred in seismic profile but missing in geological transect – lack of CPT data]

2. shallow bright reflector at NW end of profile (1700-ft to 2200-ft) correlates to top of the San Pedro Formation in the borehole data; bright reflector at similar twtt to Qsp SE of fault at 1800-ft is likely to be the same deeper bright reflector apparent at the SE end of the profile and also vaguely apparent elsewhere along the profile – borehole data are too shallow to identify this geologic horizon on Transect 1-8, but it may be the Qsp2 horizon observed along Transect 4 (and in the trench from Leighton & Associates), where the shallow Qsp1 pinches out?

3. deep bright reflectors are apparent (orange) but cannot be accurately correlated with subsurface stratigraphy (borehole data too shallow, and fault offsets substantial, so that "jump" correlation across faults is highly uncertain (note offset of Qsp at depths constrained by borehole data)

Structure

4. based on interpretation constrained by borehole and CPT profiles along Transect 1-8, a major zone of north-dipping faulting is recognized – this is the Santa Monica Fault Zone

5. although considered an oblique-reverse fault, the Santa Monica Fault Zone recognized along Transect 1-8 (and Transect 3) shows both normal separation and reverse separation – this is classic character of strike-slip faulting

6. complex zone of faulting recognized along Transect 1-8 (and possibly along Transect 3) is inferred to represent splay faulting associated with the northeast termination of the Santa Monica Fault Zone – also classic character of strike-slip faulting

7. result of strike-slip fault termination is the transformation of lateral displacement into vertical displacement to absorb the shortening accumulated on the south side of a NE-trending left-slip fault, and accommodate the extension on the north side where a pull-apart basin (releasing stepover) exists (Hollywood Basin)

8. vertical separation across San Pedro Formation (and Lakewood Formation) is significant on several fault splays with both normal and reverse components evident; the normal separation on the southern fault splays is countered by reverse separation on the northern fault splays, which creates a narrow graben along the fault zone

9. there is a south dipping monocline at the north end of the profile (also on Transect 3) – this is likely related to the uplift of the Santa Monica Mountains, possibly along other reverse fault

splays to the north of the profiles or the Benedict Canyon Fault (Wright, 1991)?

10. another common feature observed along Borderland pull-apart basins – strike-slip fault terminations tend to curve away from the basin, to the south for the Santa Monica Fault in this example – the Las Cienegas Fault (also the Rancho Fault? Wright, 1991) may represent this character; a termination bulge is created by the shortening associated with diminishing left-slip, so reverse separation would be anticipated for these structures

11. if the termination bulge hypothesis is valid, and the south bending subsurface faulting is continuous from the Santa Monica Fault Zone to the Las Cienegas Fault (as shown in oil field mapping, Wright, 1991; DOGGR and Veneco?), then the Newport-Inglewood Fault Zone is NOT continuous in the shallow subsurface to the West Beverly Hills Lineament; The NIFZ may be continuous at depth below the shallow structure, and in particular, below the main Santa Monica Mountains Thrust

12. All of the contractional structure (reverse-slip and folding) is enhanced (greatly) by the convergence of the Peninsular Ranges crustal block against the Western Transverse Ranges

13. Bad news is that we still do not understand the structural significance of the West Beverly Hills Lineament, which is clearly in the hanging wall of the Santa Monica Mountains Thrust and aligned with the NIFZ; although this may be coincidence, it is more likely related to pre-existing structural weakness inherited from the long-lived and complex tectonic history that includes middle Miocene breakaway of the WTR from the southern California continental margin, clockwise vertical-axis rotation of the WTR combined with evolution from an oblique-extensional system into the post-Miocene transpression as the Peninsular Ranges collides with the WTR following the eastward jump of the PAC-NOAM plate boundary to the Gulf of California/southern San Andreas fault system; Notwithstanding, it may be that the coincidence at this moment when the left releasing stepover of the Santa Monica-Hollywood fault zone aligns with the NIFZ allows the shallow structure to bend (flexural sag?) at this weakness (the stepover as an accommodation zone); the bending may induce shallow faulting due to the extension of the surface strata [however, one might expect cross-bedding faults due to bending to reach the ground surface where extension should be greatest – this is observed in the trenches, but does not account for the greater faulting observed in the seismic profiles; if flexural slip folding is occurring, there may be slickensides on bedding planes]

14. the graben along the Santa Monica Fault Zone in this area of active alluvial fan deposition would be expected to control the channel orientations to some extent – the borehole data show fault contacts at the San Pedro and Lakewood Formation levels, not erosional channeling, so this aspect may deserve further investigation by the geologists, and is likely to be found at shallower stratigraphic levels

15. the complex faulting and deformation pattern will likely be repeated in future large earthquakes along the Santa Monica Fault Zone – the vertical deformation is only one component of the net slip that may occur and design of structures across this zone must account for the strike-slip component as well