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Subject: **Geomorphic, structural, and stratigraphic evaluation of the eastern Santa Monica Fault Zone, and West Beverly Hills Lineament, Century City/Cheviot Hills, California.**

This is the final report requested by the Beverly Hills Unified School District. The report provides a detailed 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 regional context.

Individual reports have postulated that the West Beverly Hills Lineament is actually an extension of the Newport-Inglewood Fault Zone. They have further postulated that the Santa Monica –West Beverly Hills - Newport Inglewood – Hollywood Fault Zones are active in the Century City area, posing a serious regional seismic threat that is in conflict with the current state of intense development and urbanization.

This report specifically considers these theories in light of all available data and has concluded that they are not supported. 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 may require subsequent amendment to adjust the findings and conclusions presented in this report.

Miles D. Kenney PhD., PG
Kenney GeoScience

Distribution: Report was distributed via digital pdf files to:

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1.0 INTRODUCTION

Kenney GeoScience (KGS) was retained by the Beverly Hills Unified School District to provide a geologic evaluation of the Century City/Cheviot Hills area.

Numerous recent site-specific geologic studies have been completed or are underway by various parties within the Century City/Cheviot Hills area including the Los Angeles County Metropolitan Transportation Authority (Metro). Metro has completed a study that included potential subway station sites and the Beverly Hills High School. The Beverly Hills Unified School District has completed a study of the Beverly Hills High School. The Beverly Hills Unified School District has an ongoing study of the El Rodeo Elementary School (north of the proposed eastern Santa Monica subway station site) and private parties have ongoing studies of properties at 10000 Santa Monica (between the BHHS and the proposed eastern Santa Monica subway station site) and at the Westfield Mall (between the proposed western Santa Monica subway station site and the proposed Constellation subway station site).

1.1 Purpose and Scope of Study

The primary purpose of this analysis is to establish a regional geologic context in which to evaluate the site specific data being generated by all parties using standard geomorphic, structural and stratigraphic methods of analysis and evaluation.

1.1.1 The Century City Question

The Century City/Cheviot Hills area has long been a subject of great geologic interest because of its location near the Santa Monica, Hollywood, and Newport-Inglewood Fault Zones and specific local topographical features including the West Beverly Hills Lineament (WBHL; Figure 1). Prior to 2011, 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. (2000) that determined that the Santa Monica Fault Zone is active (Figure 2). There are series of visible scarps along Santa Monica Boulevard between the present Mormon Temple and the Los Angeles Country Club on the northern edge of Century City that have survived urban development (Figure 2; Dolan and Sieh, 1992; Dolan et al., 2000).

For this study, the Santa Monica Fault Zone of Dolan and Sieh (1992) extending from the West Los Angeles Veterans Administration Hospital property (Figure 2 – WLA VA) to eastern Century City is subdivided into two fault zones at the Mormon temple property as shown on Figure 3. Fault section A (in red) represents the approximate surface projection location of the Santa Monica Fault Zone west of the Mormon temple property which, as discussed later in this report, is believed to extend eastward as a blind reverse fault in the southern Cheviot Hills shown as fault section C (green). Fault section B along Santa Monica Boulevard extending from the Mormon temple property northeastward to the West Beverly Hills Lineament will be referred to herein as the Santa Monica Boulevard Fault Zone (SMBFZ). The general location of the West Beverly Hills Lineament eastward sloping escarpment is also shown on Figure 3 as a gray dashed line labeled D.

Figure 1: Regional fault and geology map of the northern Los Angeles Basin depicting Metro Westside Subway Extension Proposed Alignments. Modified from Parsons (2011; Figure 4)

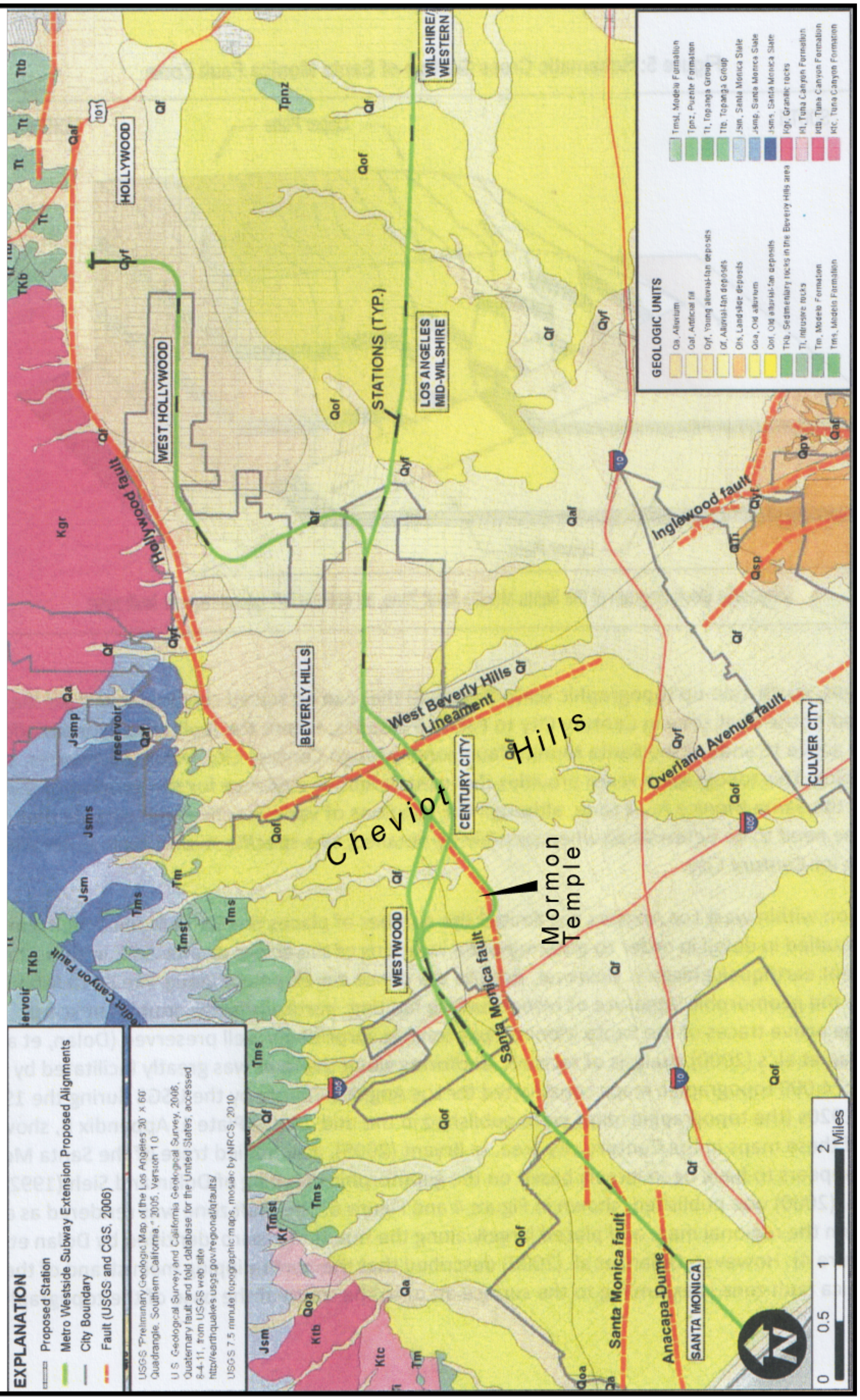


Figure 2: Local fault and geology map of the eastern Santa Monica Fault Zone depicting Metro Westside Subway Extension Proposed Alignments. The black shaded regions are identified fault scarps by Dolan et al. (2000; figure base map). Orange-yellow dashed lines represent proposed USGS and CGS fault locations (2006). Modified from Parsons (2011; Figure 6)

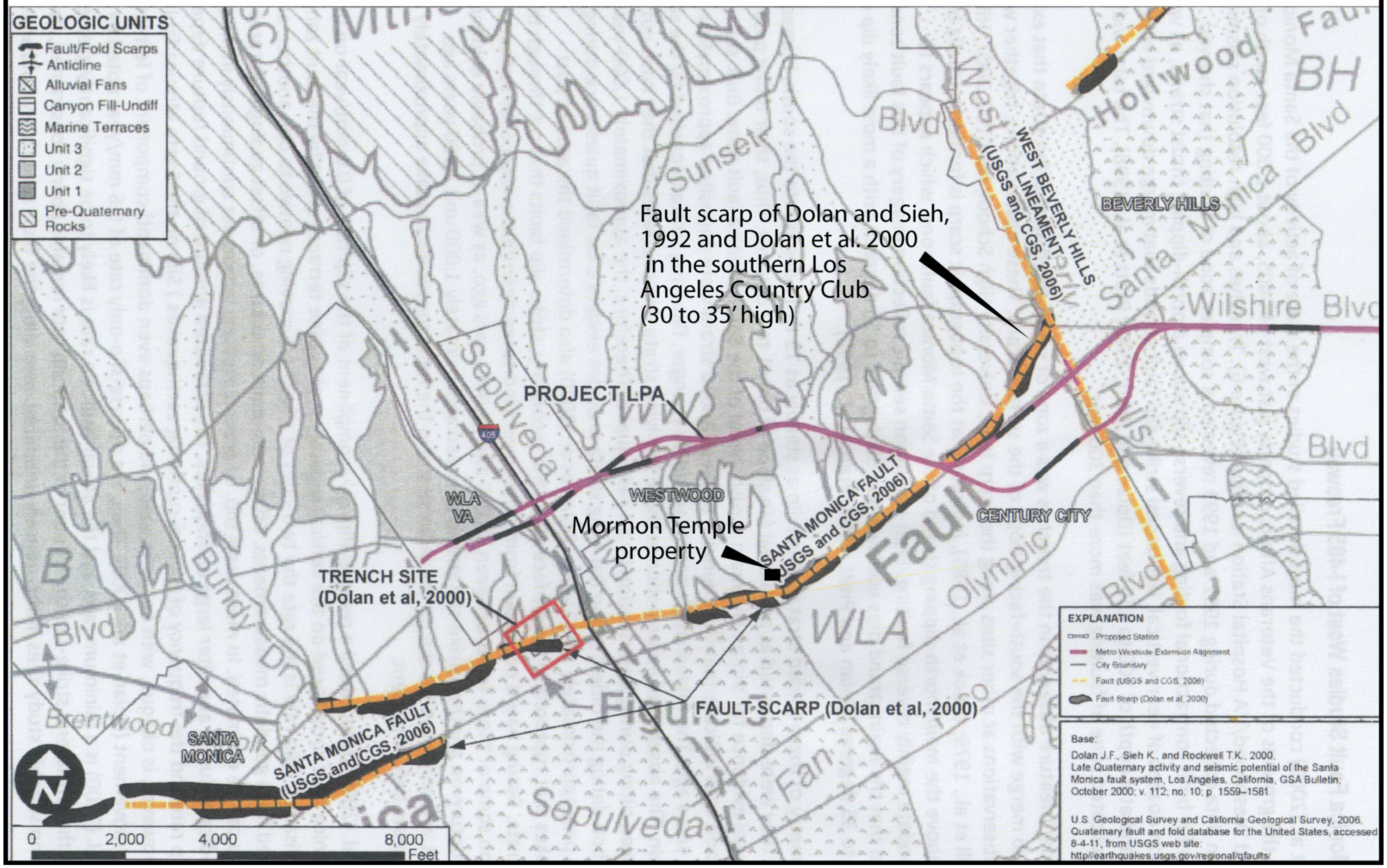
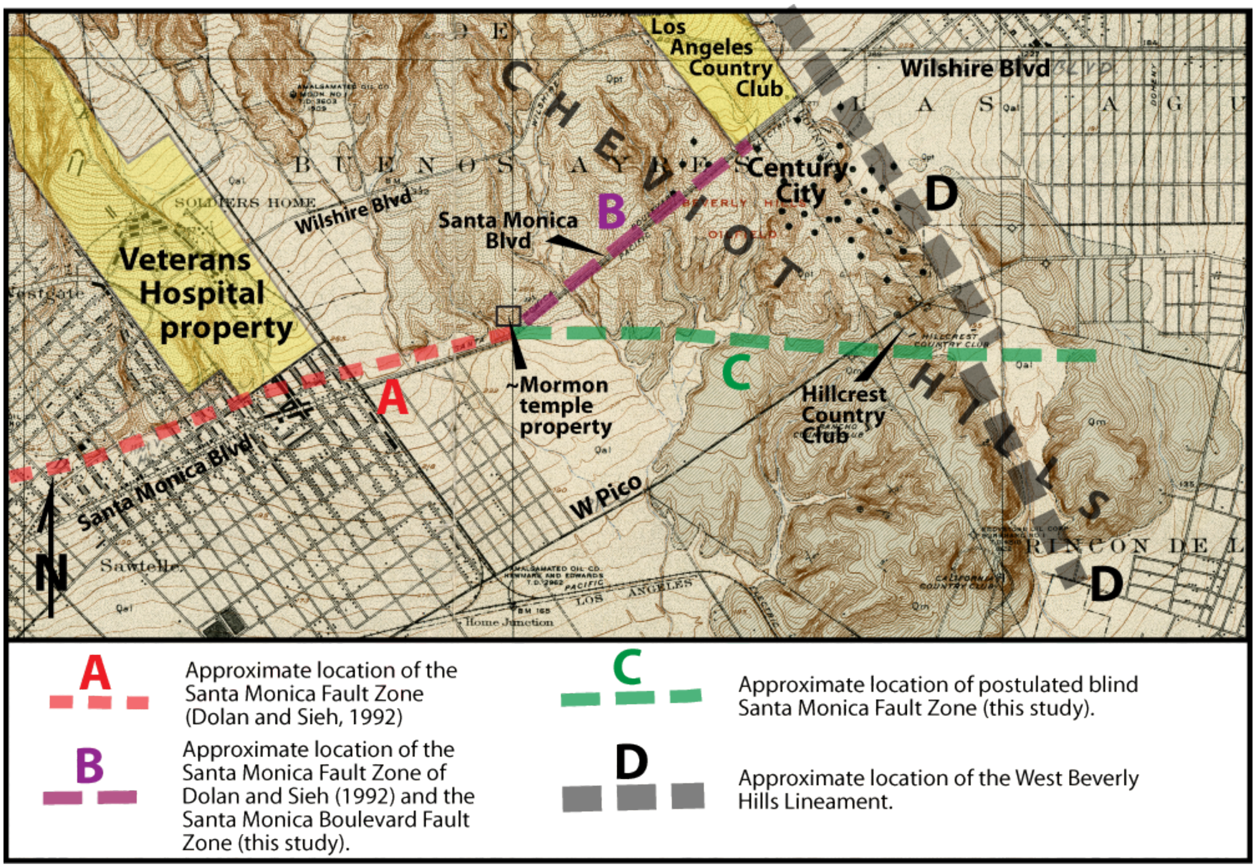


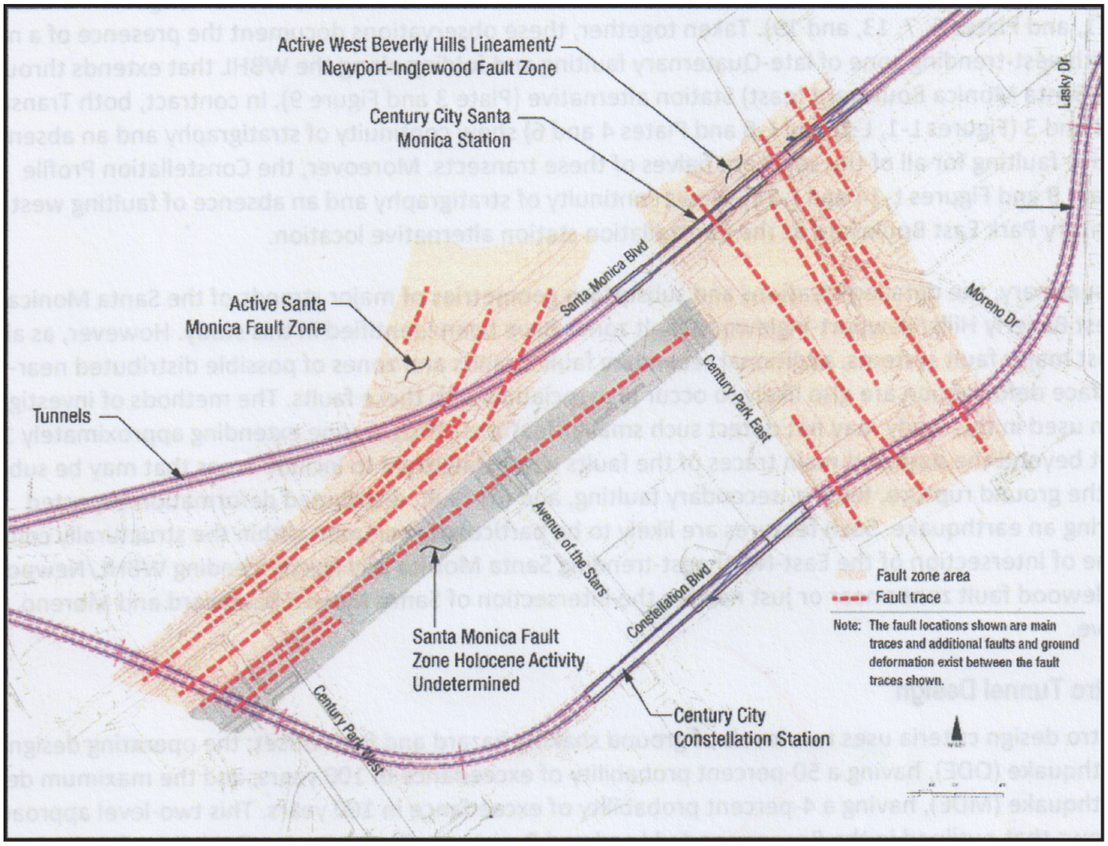
Figure 3: Santa Monica Fault Zone sections as discussed in this report.



Fault evaluation studies conducted by MACTEC (2010) and Parsons (2011) have identified 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. Figure 4 below provides the Parsons (2011) fault map identifying numerous northeast trending faults along Santa Monica Boulevard 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). However, as indicated earlier, within this study, northeast trending faults along Santa Monica Boulevard are referred to as the Santa Monica Blvd Fault Zone (SMBFZ) as shown on Figure 3.

Parsons (2011) - without any sediment age data to evaluate the age of faulting - presumed that the 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. (2000). 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 1).

Figure 4: Fault map of Parsons (2011; Figure 9); low resolution per original report.



The West Beverly Hills Lineament represents a north-northwest trending east-sloping escarpment located on the western edge of the City of Beverly Hills. Based on the existing literature it is unclear what processes produced the West Beverly Hills Lineament. 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) has posted a fault map (their website) showing a single fault in the area of the West Beverly Hills Lineament. 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 as an active fault. Some published explanations for creation of the topographic West Beverly Hills Lineament include:

- Uplift above a deep-seated northerly extension of the Newport-Inglewood Fault Zone (NIFZ; see Wright, 1991 and this study). This model therefore indicates that uplift, folding, and erosion are the dominant processes producing the West Beverly Hills Lineament.

- Faults associated with the northern extension of the Newport-Inglewood Fault Zone (Dolan and Sieh, 1992). This model suggests that faults associated with the Newport-Inglewood Fault Zone extend to the surface or very close to the surface within the West Beverly Hills Lineament. Tsutsumi et al. (2001) are essentially in agreement with this model.

- The surface manifestation of a northern extension of the gently east-dipping Compton blind thrust fault (Shaw and Suppe, 1996). This model suggests that uplift, folding and erosion led to the development of the West Beverly Hills Lineament.

- 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.

- Lang and Dreesen (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.

- Hummon et al., (1994) indicate that the broad west-plunging anticline produced by the Wilshire fault, the axis of which is parallel to Wilshire Boulevard east of the Cheviot Hills terminates westward at the West Beverly Hills Lineament. Our interpretation of this model suggests that Hummon et al. (1994) indicate that a structural “break” occurs across the West Beverly Hills Lineament that is likely associated with faulting.

- 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 a steeply 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 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.

- It should be pointed out that Shaw and Suppe (1993) indicate that the slip rate on the northern Newport-Inglewood Fault Zone south of the Cheviot Hills is estimated to be <0.1 mm/yr and Tsutsumi et al. (2001) suggest that the slip rate of the Newport-Inglewood Fault Zone should decrease toward the north. This is consistent with Wright's (1991) proposal that the Newport-Inglewood Fault Zone has propagated northward during the late Quaternary.

Based on all these different models it is clear that the West Beverly Hills Lineament is an important late Quaternary structural feature within a complex tectonic region of converging folds and various fault zones but remains poorly understood. The models are consistent in regards to indicating that faulting or folding were the primary structural processes involved in the creation of the West Beverly Hills Lineament.

If the West Beverly Hills Lineament is indeed attributed to faulting, and if the Santa Monica Fault Zone actually extends to Century City along Santa Monica Boulevard, then there is a logical temptation to simply extend and "connect the dots" and conclude that the West Beverly Hills Lineament is actually an extension of the Newport-Inglewood Fault Zone, that the Newport-Inglewood Fault Zone probably connects to western terminus of the Hollywood Fault, and that Century City sits at the confluence of the Santa Monica Fault and the West Beverly Hills Lineament - Newport-Inglewood Fault Zone. The lack of any detailed subsurface data in the immediate area has prevented resolution of the underlying questions. As discussed previously, it is clear that the West Beverly Hills Lineament is indeed a topographic lineament (escarpment), but it is unclear what natural processes created it - faulting, folding, uplift, erosion or a combination of these processes. In addition, if the West Beverly Hills Lineament primarily resulted from faulting then are these faults active as defined by the State of California?

The lack of resolution has not prevented urban development. Century City itself is now heavily developed with high-rise buildings, and the surrounding areas that may overly the various suspected faults are completely developed and urbanized.

1.1.2 The Westside Subway Extension Studies

During the past year and a half, the first fault investigations providing subsurface data in the Century City area were conducted as part of the design studies for the Los Angeles County Metropolitan Transportation Authority Westside Extension subway project. Both the MACTEC (2010) and Parsons (2011) investigations for Metro provided subsurface data to evaluate potential fault locations associated with the generally northwest to southeast trending West Beverly Hills Lineament (WBHL) and the generally southwest to northeast trending Santa Monica Fault Zone (SMFZ). The Parsons (2011) investigation and public testimony by experts who participated in the investigation made numerous and significant conclusions regarding the presence of faulting in the Century City area:

- The Santa Monica Fault Zone extends across the northern edge of Century City.

- The West Beverly Hills Lineament is actually the northern part of the Newport-Inglewood Fault Zone extending from Century City to possibly further north where it intersects the western terminus of the Hollywood Fault near the base of the Santa Monica Mountains.

- The data supported a map of numerous fault strands of both the Santa Monica and West Beverly Hills Lineament fault systems, which intersect along Santa Monica Boulevard.
- The data supported the mapping of a broad swath of active faulting (fault zone) with the potential for surface disruption within the State of California definition of an active fault (younger than 11,000 years).
- Because of the presence of active faulting as mapped by Parsons (2011) two of the three potential subway station locations in Century City were declared unsafe and should not be considered.
- The existing Beverly Hills High School campus overlays numerous active faults.

Although the purpose of the Metro studies was to assist in subway design, the conclusions and public pronouncements made by Parsons (2011) have public implications that go well beyond the immediate questions of subway planning and design. **These conclusions are not supported by the data or by rigorous analysis and are not consistent with emerging data and analysis from other sources.**

There are certain obvious limitations in the scope of the Metro field investigations. Some of these include the disproportionate reliance on CPT data with relatively few continuous core borings or other method of result confirmation, and a lack of any fault trenching or age dating of the local sediments. The MACTEC (2010) and Parsons (2011) fault investigation reports provided absolutely no data regarding fault activity because neither study provided any quantitative sediment age data. There was no trenching or positive identification at the surface of any fault within the study area. Their studies also did not provide any fault strike data with the exception of attempting to connect certain faults identified on local transects which by its nature is speculative. Despite the lack of data, several faults within each zone were identified as "Active" on the published Parsons (2011) maps.

Kenney GeoScience disagrees with many of the Parsons (2011) interpretations and believes that the findings within their report should have been considered preliminary and followed up with additional studies both to better resolve the actual locations and existence of faults and their activity level in the study area. In addition, it is clear that more subsurface data needs to be collected for the proposed subway station locations.

1.1.3 The Beverly Hills High School Studies

After the release of the Parsons (2011) report, Leighton Consulting Inc. (LCI) conducted an extensive fault investigation within the Beverly Hills High School property. The LCI (2012) investigation is significant because it is the only field investigation in the immediate Century City area to have conducted large scale trenching directly across the Parsons (2011) proposed faults within the West Beverly Hills Lineament – Newport Inglewood fault zone (WBHL-NIFZ).

The LCI (2012) fault investigation focused on whether or not the proposed northwest to southeast trending faults associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone exist. The study also provided considerable age data for the near surface sediments to evaluate whether or not any faults that may exist in the area should be considered as "active" under State of California definitions. Simply put, LCI (2012) determined that no active near surface faults exist in the Beverly Hills High School property associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone. This conclusion diverges significantly from the Parsons (2011) conclusion.

The LCI (2012) investigation is also significant because it attempted to replicate a series of Parsons (2012) CPT tests along Transect 4 with their own closely spaced continuous core borings and CPT tests. This confirmation testing revealed certain discrepancies in the Parsons (2011) CPT data when compared against the LCI continuous core borings and CPT tests.

The most recent publication to emerge regarding potential subsurface faulting is Parsons (2012) entitled "Response to Leighton Consulting Report" dated May 14, 2012. This report provided adjusted locations for the West Beverly Hills Lineament-Newport-Inglewood faults on the Beverly Hills high School campus proposed by Parsons (2011). Where an LCI (2012) fault trench and boring series showed that a Parsons (2011) proposed West Beverly Hills Lineament-Newport-Inglewood fault did not exist, Parsons (2012) either shortened the proposed fault length so that it did not extend to the LCI (2012) trench, or moved the fault location slightly to just slide between a small gap between LCI trench locations. The Parsons (2012) response report provided no new data to explain these adjustments or to reconcile the inconsistencies between Parsons (2011) and LCI (2012) on Transect 4. The Parsons (2012) response report did provide new data consisting of a subsurface structure contour map of the upper San Pedro Formation surface. Parsons (2012) interpreted deformation evaluated in this contour map as evidence that a northwest-southeast trending fault within their West Beverly Hills Lineament fault zone exhibits approximately 350 feet of right-lateral displacement.

The Parsons (2011 and 2012) analysis of the West Beverly Hills Lineament and mapping of active faults across the Beverly Hills High School remains sharply at odds with the LCI (2012) data and findings. This contradiction in actual LCI (2012) findings versus Parsons (2011) predictions, the apparent issues with the Parsons (2011) CPT data and its repercussions, the lack of soil dating, and other analytical limitations in the Parsons (2011) study raise serious questions regarding the overall Metro study methodology and conclusions regarding the overall Century City area. Again, the MACTEC (2010) and Parsons (2011) fault studies are considered good preliminary fault investigations especially taking into account the density of urban development. These studies essentially provided a model for the potential location of faults but provided no data regarding whether or not the faults really exist and if so their activity. Their preliminary data should have been utilized for developing a more refined subsurface study in the area of their identified faults to determine whether or not the faults exist and their activity as defined by the State of California.

It is also clear that accurate interpretation of this data cannot be done out of context: it requires interpretation consistent with all of the known geologic facts and attributes of the overall Century City area. Even after the MACTEC (2010), Parsons (2011 and 2012), and LCI (2012) reports and the many preceding papers on the subject, many questions remain regarding potential deformation associated with the Santa Monica and proposed West Beverly Hills Lineament –Newport-Inglewood Fault Zone within the Century City area. Some of these include:

- What is the geologic history of the Century City area since the late Pleistocene?

- What was the tectonic role of local folding in the Cheviot Hills? What caused the uplift and erosion in the Cheviot Hills to produce the West Beverly Hills Lineament?

- Are the faults along Santa Monica Boulevard active?

- Do faults associated with the West Beverly Hills Lineament exist in the near surface in the Century City and Beverly Hills area?

- Could blind active faults exist in the Cheviot Hills area?

- Why do the identified faults along Santa Monica Boulevard dip approximately 20 to 30 degrees at the Veterans Hospital property (Pratt et al., 1998; Catchings et al., 2008) located approximately 2 miles west of Century City, and then dip approximately 50 to 85 degrees in the Century City area? What does this imply?

- Are the faults identified along Santa Monica Boulevard actually the primary basal Santa Monica Fault Zone?

- Why do many of the faults identified in the Parsons (2011) report along Santa Monica Boulevard show apparent normal and reverse dip-slip separation?

- Does a releasing bend occur along the Santa Monica Fault Zone locally in the Century City area parallel to Santa Monica Boulevard?

- Are the faults identified along Santa Monica Boulevard actually secondary faults to the basal reverse fault of the Santa Monica Fault Zone?

- Has the primary basal reverse fault to the Santa Monica fault Zone in the Cheviot Hills yet to been identified?

1.2 Report Conclusions

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

- A late Quaternary geologic history has been developed for the Cheviot Hills based on all the provided data that greatly assists in our understanding of the timing and scale of local deformational structures and sedimentary units in the Cheviot Hills.

- A detailed geomorphic analysis of the Cheviot Hills is presented that provides improvements in our understanding of the style, age, and location of faults in the Cheviot Hills region.

- No conclusive evidence has been published that <u>any</u> faults in the Cheviot Hills (Century City area) are active. Based on published geologic mapping, age dating of near surface sediments, geomorphology, evaluation of the geologic history of the local area, and revised interpretation of the Parsons (2011) transect cross sections, there is a possibility that none of the faults along Santa Monica Boulevard, referred herein as the Santa Monica Boulevard Fault Zone (SMBFZ) are active. The data suggest that activity on various individual faults within the fault zone likely ceased at different times. Based on the existing data, the Santa Monica Boulevard Fault Zone was active approximately 150,000 years ago, offsets a soil profile dated at approximately 134,000 years old, and may have ceased prior to approximately 40,000 to 50,000 years ago. Therefore, faults within this zone should not be considered active until a more detailed subsurface fault investigation is conducted and they are determined to be active by direct evidence.

- It is probable that active folding is occurring in the Cheviot Hills and thus may potentially affect proposed subway stations on either Santa Monica or Constellation. The rate of folding is considered low to very low (i.e. per major earthquake event) but this aspect of the local geology should be more fully evaluated by professional geologists and engineers. Kenney GeoScience has concluded that the West Beverly Hills Lineament was produced by folding, and not near surface faulting. For strain budgets, it is clear that fault displacement estimates should consider local folding as a slip sink.

- Faults associated with the proposed northwest trending West Beverly Hills Lineament – Newport-Inglewood Fault Zone likely do not exist in the study area along the West Beverly Hills Lineament. The West Beverly Hills Lineament resulted from concurrent folding (uplift of Century City) and erosion by the Benedict Canyon Wash that produced a fold-scarp as proposed by Dolan et al. (1997).

- Parsons (2011) presumed that many soil layers were essentially horizontal which led to the false positive identification of numerous faults within their West Beverly Hills Lineament - Newport-Inglewood Fault Zone.

- The Benedict Canyon Wash has had a significant defining role in the Cheviot Hills region since the late Quaternary. Today, it is a northwest-southeast trending drainage that has contributed significantly to the erosional and depositional patterns that in addition to local uplift contributed to the creation the West Beverly Hills Lineament. In the past, the Benedict Canyon Wash flowed southwest across the northern edge of Century City and through the Cheviot Hills. Parsons (2011) did not identify the older Benedict Canyon Wash Deposits (BCWD) in terms of their geologic significance.

- A regional tectonic kinematic model is proposed for the creation of the West Beverly Hills Lineament that is associated with the Newport-Inglewood Fault Zone (NIFZ); however, these faults are not required to reach the surface in the eastern Cheviot Hills. Essentially the model proposes that the Newport-Inglewood Fault Zone extends into the eastern Cheviot Hills beneath the Santa Monica Fault Zone similar to a model proposed by Wright (1991). Thus, as the Santa Monica tectonic block, defined as west of the Newport-Inglewood Fault Zone and south of the Santa Monica Fault Zone, moves toward the north along the Newport-Inglewood Fault Zone, it simply deforms the basal Santa Monica Fault Zone and causes uplift in the Cheviot Hills in a region parallel to and above the subsurface Newport-Inglewood Fault Zone. This uplift caused the development of northwest-southeast striking folds in the general area of the West Beverly Hills Lineament. As the uplift continued, erosion associated with Benedict Canyon Wash occurred along the strike of the uplift thus creating the east facing, northwest-southeast striking escarpment referred to as the West Beverly Hills Lineament. This model allows for the Newport-Inglewood Fault Zone to be the causative agent for the development of the West Beverly Hills Lineament, but does not require faults associated with the Newport-Inglewood Fault Zone to exist at the near surface (above the underlying Santa Monica Fault Zone). The model also allows for northern fault strands of the Newport-Inglewood Fault Zone to exist near or at the surface in the southeastern Cheviot Hills south of the proposed location of the blind north-dipping reverse Santa Monica Fault Zone.

- Parsons (2011) concluded that northwest to southeast trending active faults associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone (WBHL-NIFZ) extended to and across the Beverly Hills High School and the proposed eastern Santa Monica Boulevard subway station site. The proposed northwest to southeast trending active faults associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone simply do not exist in the near surface in the study area (i.e. the maximum depths of all currently published investigations). One fault was identified by LCI (2012) in the Beverly Hills High School property (Fault Trench 3) but was determined to be inactive, did not exhibit a thick gouge zone, and the total apparent offset across the fault was likely in the range of a few feet. Thus, it appears likely based on the existing data that a relatively major strike-slip fault system associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone does not exist in the near surface at least in the area where sufficient subsurface data has been collected (i.e. region of the LCI, 2012 and Parsons, 2011 studies). Therefore, faults associated with the Newport-Inglewood Fault Zone may occur further east of the study area and the West Beverly Hills Lineaments.

- The primary fault zone in the study area occurs in the general vicinity of Santa Monica Boulevard, and is referred herein as the Santa Monica Boulevard Fault Zone (SMBFZ). The Santa Monica Boulevard Fault Zone is defined as a series of faults that trend parallel to Santa Monica Boulevard between the Mormon Temple through Century City and into western Beverly Hills (Figure 3). Faults within the Santa Monica Boulevard Fault Zone predominantly dip steeply toward the north and likely exhibit primarily right-lateral displacement with local secondary reverse and normal displacement dependent on their strike within the zone (i.e. local restraining and releasing orientations). Our findings regarding the general location of these faults are in close agreement with Parsons (2011) however Kenney GeoScience is in disagreement regarding the kinematic role of the Santa Monica Boulevard Fault Zone and its potential age.

- The Santa Monica Boulevard Fault Zone splays outwards towards the east in the study area, and thus, the faulting at various scales is likely complex and exhibits numerous relatively smaller scale faults that would prove difficult to identify based on the resolution of the existing data.

- Based on the evaluated data, many if not all of the faults within the Santa Monica Boulevard Fault Zone are not active. The presumption that this fault zone is active is not supported by any local data. A number of individual faults within this zone are shown to be inactive by Parsons (2011) and additional analysis provided herein indicates the possibility that the vast majority if not all of the faults in the Santa Monica Boulevard Fault Zone are not active in terms of rupturing the surface during the past 11,000 years as defined by the State of California (Bryant and Hart, 2007). Further investigations to analyze fault activity within this zone are strongly warranted and should be conducted within the area of mapped older Benedict Canyon Wash Deposits.

- Based on evaluation of the geophysical seismic reflection data provided in the Parsons (2011) report, some relatively deep and possibly inactive faults may occur south of the identified Santa Monica Boulevard Fault Zone as shown by Parsons (2011). These faults are poorly understood but may provide some insights on the tectonic and structural evolution of the region in addition to potential seismic hazards. For example, have faults similar to the Santa Monica Boulevard Fault Zone migrated toward the north over time, and thus suggest a possible bend in the underlying primary basal reverse Santa Monica Fault? Could these faults be active and are simply blind and thus producing local near surface folding?

- Numerous lines of evidence suggest that the Santa Monica Boulevard Fault Zone is a secondary upper plate fault zone associated with the basal oblique left-lateral reverse Santa Monica Fault Zone. This conclusion infers that the basal Santa Monica Fault Zone has not yet been identified in the Cheviot Hills and if it does exist would likely occur in the southern Cheviot Hills.

- This hypothesis therefore suggests that the basal Santa Monica Fault Zone reverse fault exists in the southern Cheviot Hills, that all the sediments of the Cheviot Hills are in the upper plate and thus could exhibit active folding and secondary faulting. Based on this hypothesis, it is conceivable that the Santa Monica Boulevard Fault Zone could actually be inactive even if the basal Santa Monica Fault Zone reverse fault remained active in the area. All of these factors greatly affect estimates regarding how fault displacements would be partitioned in the area during a major earthquake in addition to a lack of understanding regarding the western reaches of the Hollywood Fault Zone.

- One, and possibly two fault strands identified by Parsons (2011) as part of their proposed West Beverly Hills Lineament fault zone are actually extensions of fault strands that exist within the Santa Monica Boulevard Fault Zone.

The conclusions of this report regarding the proposed Metro Westside Subway Extension Project include:

- Several strands of the Santa Monica Boulevard Fault Zone cross the western proposed Santa Monica subway station site (but not the proposed central site proposed by Beverly Hills Unified School District or the eastern site proposed by Metro). The evidence is that most if not all of these strands are inactive. Additional field investigations would be required to confirm that the shallowest faults are or are not active, and to investigate whether or not smaller scale faults (i.e. <3 to 5 feet of vertical displacement) may exist in these areas.

- Based on the existing data, no faults were identified that transect or trend toward the proposed central or eastern Santa Monica subway station sites.

- A series of northeast-southwest trending, relatively deep faults may extend across the site just north or possibly through the proposed Constellation subway station. The primary evidence of these faults is provided by evaluation of the Parsons (2011) seismic reflection data and the Parsons (2012) structure contour map. Insufficient data exists in the region of the proposed Constellation subway station to evaluate whether or not relatively major faults occur in this area, and thus warrants additional investigation.

- Late Quaternary folding occurs in the Cheviot Hills that should be evaluated by professional geologists and engineers in terms of potential impacts to proposed and possibly existing structures.

It should be noted that additional investigations are currently underway by private parties that have been negatively affected by the Metro studies.

- The approved high-rise project at 10000 Santa Monica (immediately between the eastern proposed Santa Monica subway station and the Beverly Hills High School) has excavated geologic trenching to provide further confirmation of the absence of north-south West Beverly Hills Lineament-Newport-Inglewood Fault Zone active faulting. Formal results have not been released however there is obvious continuity of older soil layers and no indication of faults in the trench.

- This project may also be required to conduct north-south trenching to establish dating of the known east-west Santa Monica Boulevard Fault Zone faults that cross the site (identified in this report and by others, but strongly suspected to be older and inactive).

- Similarly, the Westfield Mall (located between Santa Monica Boulevard, Avenue of the Stars, Constellation and Century park West) that has already obtained zoning permits for a $1 billion redevelopment is beginning a geologic exploration plan that will address the presence and age of predicted Santa Monica Boulevard Fault Zone – the same faults that were predicted by Metro to cross the western Santa Monica subway station site.

Unlike the Metro studies, these investigations are subject to regulatory oversight and review: these investigations must specifically address the presence or absence of active Santa Monica Boulevard Fault Zone faulting to the satisfaction of the City of Los Angeles Building and Safety Department as part of its standard permitting process. The emerging data stream is consistent with the conclusions of the Kenney GeoScience analysis and the conclusions presented herein.

2.0 SCOPE OF THIS 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 for Metro and Beverly Hills High School. While 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), the proposed Metro subway station sites along Santa Monica Boulevard and the proposed Metro subway station site on Constellation Boulevard (Plate ES-1a), the implications of this work for the existing and future urban development of the surrounding area is fully recognized.

The Kenney GeoScience analysis provides a preliminary geologic and tectonic history regarding the age and history of sedimentation, erosion, uplift, folding and faulting in the Century City area. The Kenney GeoScience analysis has intentionally sought out multiple lines of overlapping inquiry: conclusions based on more than one methodology are more robust than conclusions based on a single line of data and analysis. Also, any conclusions reached should make sense in the overall geological context of an area. The actual Kenney GeoScience inquiry methodology was incremental and overlapping.

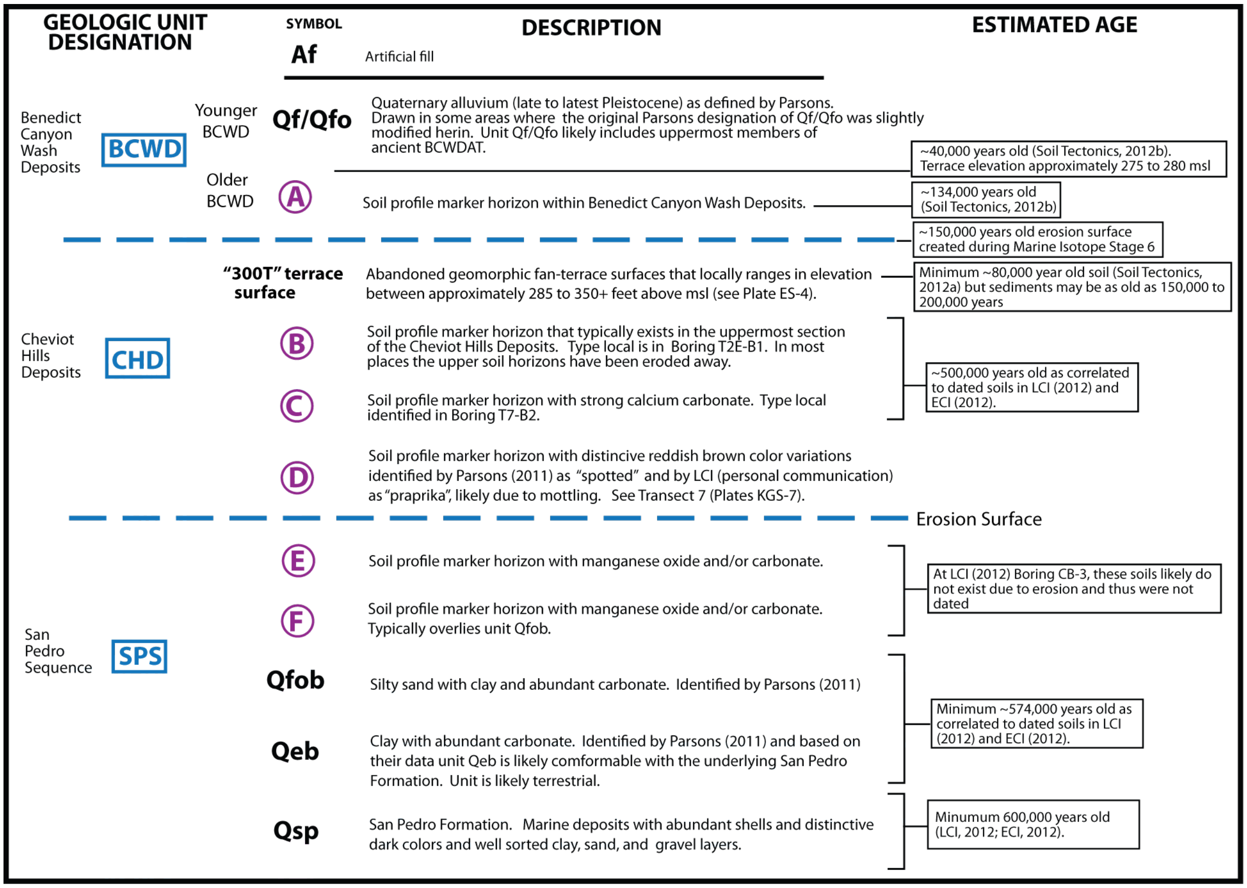
The end question of importance relates to determining fault activity. It is very difficult to evaluate fault activity without good age data. Accurately establishing age data most frequently starts with an understanding of the local stratigraphy. Understanding stratigraphy cannot be done without understanding the geologic history. And so on. The analysis has led to the following proposed geologic and tectonic history that explains the age and history of sedimentation, erosion, uplift, folding and faulting in the Century City area. The results are presented in the following sequence:

- Local Quaternary stratigraphic framework
- Age data for the designated geologic units and terraces
- General late Quaternary evolution of the Cheviot hills
- Evaluation of subsurface data
- Geomorphic evaluation of the Cheviot Hills
- Sense of slip on the Santa Monica Fault Zone
- Santa Monica Fault Zone structure
- Late Quaternary folding in the Cheviot Hills
- West Beverly Hills Lineament-Newport-Inglewood Fault Zone
- Activity of the Santa Monica Boulevard Fault Zone
- Late Quaternary deformation and depositional history in Century City (Cheviot Hills)
- The Newport-Inglewood Fault Zone in the Cheviot Hills
- Conceptual tectonic model for the Cheviot Hills and surrounding region
- Fault source parameters of the Santa Monica Fault Zone

3.0 QUARTERNARY STRATIGRAPHIC FRAMEWORK

The upper 200 feet of geologic sediments have been designated into three distinct depositional units based on age, depositional environment, and structure (deformational history) that include from youngest to oldest: the Benedict Canyon Wash Deposits (BCWD), the Cheviot Hills Deposits (CHD), and the San Pedro Sequence (SPS). Figure 5 (also Plate ES-3) show the designated local stratigraphy. 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.

Figure 5: Stratigraphic section for the Cheviot Hills in the Century City area. (Also shown on Plate ES-3.)



3.1 Benedict Canyon Wash Deposits (BCWD)

Benedict Canyon Wash Deposits (BCWD) are divided into younger and older sediments as shown on Plates ES-1a, ES-1b, ES-2a and ES-2b. The younger Benedict Canyon Wash Deposits are thin (~5 to 14 feet deep) laid down by Benedict Canyon wash in the latest Pleistocene to Holocene. The older Benedict Canyon Wash Deposits were deposited by a former southwest drainage that cut through the Cheviot Hills an estimated 150,000 to 200,000 years ago. The older channel filled with sediments between approximately 200,000 to 40,000 years ago inferentially primarily during Marine Isotope Stages 3 and 5 (MIS 3-5; Plate KGS-T1). Thus, older Benedict Canyon Wash Deposits were deposited in channels created during erosion associated with low sea level stands of Marine Isotope Stage 6. One ancient channel cut through the Cheviot Hills and flowed southwest, and a second flowed south along the WBHL near the current Benedict Canyon Wash. The Beverly Hills High School resides on a high-level geomorphic surface where the two ancient channels divided (Plate ES-1a). The older Benedict Canyon Wash that flowed through the Cheviot Hills was abandoned approximately 40,000 years ago forcing the modern Benedict Canyon Wash Deposits to flow east essentially where Benedict Canyon Wash is presently located. The basal Benedict Canyon Wash Deposits overlie an erosion surface 35 to 55 feet deep, that formed during the glacial maximum of MIS 6.

3.2 Cheviot Hills Deposits (CHD)

The Cheviot Hills Deposits (CHD) is defined as underlying the younger and older Benedict Canyon Wash Deposits, where they exist, and overlying the San Pedro Sequence (SPS) across an unconformity. The Cheviot Hills Deposits are terrestrial and represent distal fan deposits containing fining upward fluvial deposits, mud and debris flows, and multiple buried paleosols. Where Benedict Canyon Wash Deposits do not occur, the Cheviot Hills Deposits are exposed and dissected exhibiting numerous fluvial-fill terraces (see Plate ES-4). Most of the Beverly Hills High School is located on an elevated fan-terrace of exposed Cheviot Hills Deposits. These upper members are a minimum of approximately 80,000 years old (Soil Tectonics, 2012a) but as will be discussed later, are likely in the range of 150,000 to 200,000 years old. Members of the Cheviot Hills Deposits just below the basal Benedict Canyon Wash Deposits erosion surface at depths of 35 to 55 feet are estimated to be approximately 500,000 years old based on correlation with numerically dated sediments in the Beverly Hills High School (LCI, 2012; ECI, 2012).

3.3 The San Pedro Sequence (SPS)

The oldest designated sediments pertain to the San Pedro Sequence (SPS). The San Pedro Sequence includes the marine San Pedro Formation and some overlying terrestrial sediments, some of which consist of Parsons (2011) members Qfob and Qe. The top of the San Pedro Sequence is a fairly distinct erosional surface at the base of the Cheviot Hills Deposits that in some study area locations represents an angular unconformity. Hence, there is evidence that the SPS sediments were deformed prior to deposition of the overlying Cheviot Hills Deposits.

4.0 AGE DATA FOR THE DESIGNATED GEOLOGIC UNITS AND TERACES

Numerical and relative ages were determined for relict surfaces and buried paleosols from trench exposures and boring cores at the Beverly Hills High School (LCI, 2012) and for this study a test pit excavated on a prominent fan-terrace surface identified in the Cheviot Hills area (Soil Tectonics, 2012a; Plate ES-1a). The soil stratigraphic reports by ECI and Soil Tectonics are provided in Appendix B. The dated soils from borings, trenches and pits are correlated across the site (Plate ES-1a) and in the subsurface based on re-evaluated cross sections along Parsons Transects T1, T2-2E, T4 and T7 (Plates KGS-T1, KGS-T2, KGS-T4 and KGS-T7). The soil ages and relative to Geologic units are provided below.

4.1 Age of Younger Benedict Canyon Wash Deposits (BCWD)

The younger Benedict Canyon Wash Deposits (BCWD) are primarily exposed in the Benedict Canyon Wash and on a planar fan surfaces to the east (see Plate ES-1a). Similar age sediments bound the Cheviot Hills as shown as green areas on Plate ES-1b. Thin younger Benedict Canyon Wash Deposits also fill narrow canyons within the Cheviot Hills. The age of basal sediments of younger Benedict Canyon Wash Deposits is defined herein as temporally correlating with abandonment of the older Benedict Canyon Wash Deposits channel that flowed southward through Century City which is estimated to be ~40,000 years old (Plate ES-1a). The base of the younger Benedict Canyon Wash Deposits

(~40,000 years old) is exposed in LCI (2012) Fault Trench FT-2 at a depth of approximately 14 feet (ECI, 2012).

4.2 Age of older Benedict Canyon Wash Deposits (BCWD)

Older Benedict Canyon Wash Deposits occur as exposed sediments within the Cheviot Hills (Plate ES-1b) and as unexposed sediments underlying younger Benedict Canyon Wash Deposits east of the Cheviot Hills. Older Benedict Canyon Wash Deposits are preserved at the surface within the south flowing paleo-channel in Century City (Plate ES-1a). Older Benedict Canyon Wash Deposits in this area exhibit a preserved, but degrading surface (fan-terrace) ranging in elevation from about 275 to 280 feet. A minimal age estimate, based on relative soil profile development of this surface is ~41,000 years (LCI, 2012, boring CB-13). The soil dated at ~40,000 years old in LCI (2012) FT-2 (Soil Profile No.3, Station 2+215, Soil Tectonics, 2012b), probably identifies the original slope of the Cheviot Hills after cessation of older Benedict Canyon Wash Deposits deposition (Plate ES-1a).

A prominent soil and marker bed (Parsons, 2011 marker bed ME in boring T4-B1; soil marker horizon A herein) was identified in CB-13 at ~25 feet. Soil Tectonics (2012b) estimated a minimum age for this soil of 134,000 years. Inferentially, therefore, the basal older Benedict Canyon Wash Deposits erosion was cut during a glacio-eustatically controlled low sea level about 130,000 to 175,000 years ago (Marine Isotope State 6 [MIS-6]; Figure 6). The depth of this erosion surface is up to 40 to 55 feet deep but also occurs at the surface where older Benedict Canyon Wash Deposits are in contact with exposed Cheviot Hills Deposits.

4.3 Age of the Cheviot Hills Deposits (CHD)

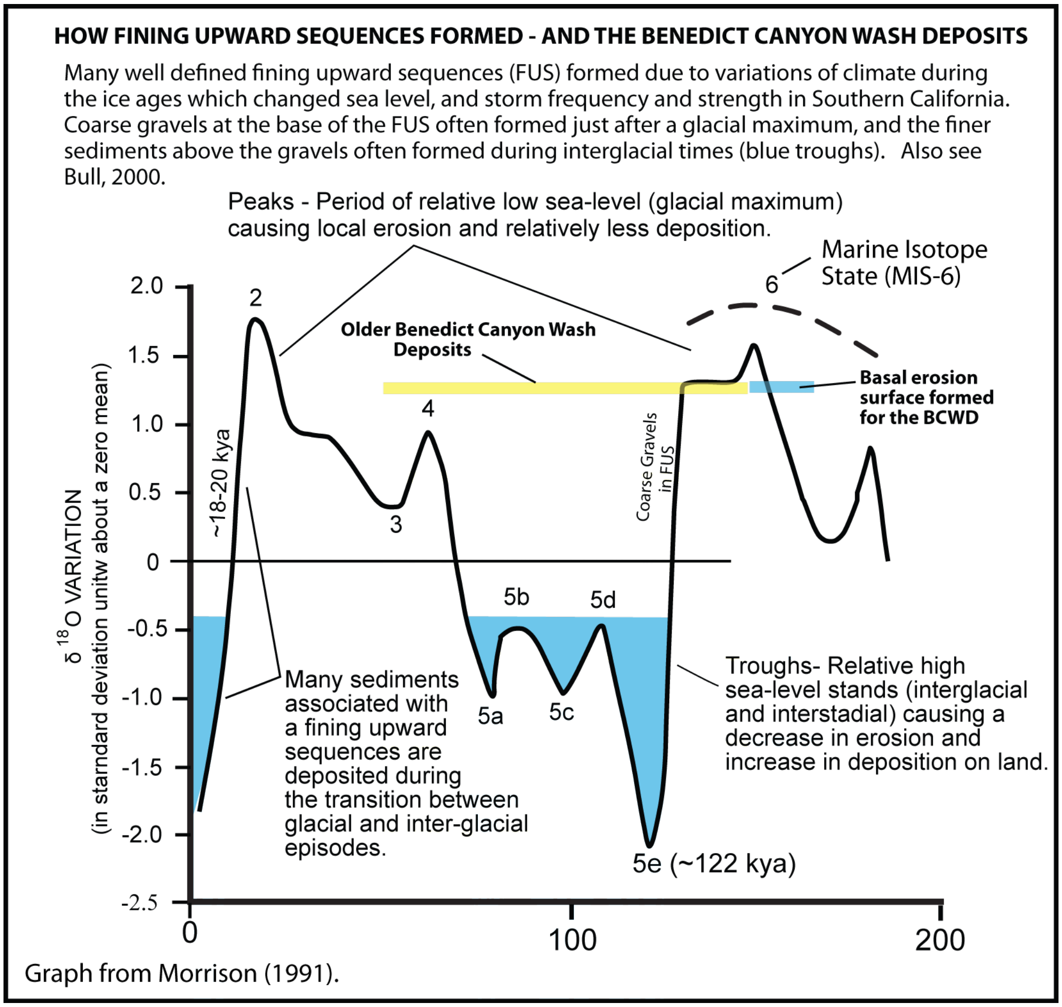
Age estimates for Cheviot Hills Deposits are provided from numerically dated soils identified in fault trenches, pits, and boring cores (LCI, 2012; ECI, 2012; Soil Tectonics, 2012a and 2012b). Estimated ages for the fan-terraces and deeper members of the Cheviot Hills Deposits are discussed separately below.

4.3.1 Age of the "300T" surface

The highest geomorphic preserved terrace in the study area is referred to as the "300T" surface (Plate ES-4), ranging in elevation from 280 to ~430+ feet, however it is also present at higher and lower elevations throughout the Cheviot Hills (see Plate ES-4) and represents cessation of deposition of the Cheviot Hills Deposits in the area. The minimum age of the surface is 80,000 years based on relative development of its capping soil (Soil Tectonics, 2012a) as exposed in a test pit on Wilshire Boulevard (Plate ES-1a). ECI (2012) also described the same surface soil as exposed in fault trench FT-1 and within 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 (2012), indicated this information regarding the age of the upper most soil in LCI (2012) 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)."*

Figure 6: Marine Oxygen Isotope Curve (MIS), from present to 200,000 years ago (Morrison, 1991). Low sea level during glacial maxima caused local erosion (channel incision) in the Los Angeles Basin (i.e. MIS 2, 4 and 6), and these canyons typically filled in with sediment during interglacial periods (i.e. MIS 5a through 5e).



Given that soil ages are minimum, and based on the geologic history as deduced here, the 300T fan-terraces were abandoned with the onset of deep erosion in the Cheviot Hills apparently associated with regionally lower base levels during MIS-6 approximately 150,000 to 200,000 years ago (Figure 6). The uppermost sediments of the Cheviot Hills Deposits were deposited during the interglacial high sea level stand of MIS 7 approximately 200,000 years ago. Therefore, based on the likely geologic history of the area, the age of the upper CHD and truncating 300T fan-terraces are probably 150,000 to 200,000 years old.

4.3.2 Age of Lower (Older) Cheviot Hills Deposits

The oldest Cheviot Hills Deposits are a minimum of 540,000 years old based on stratigraphic position and estimated soil ages. Because soil dates are minimum and because some soils are likely truncated and eroded the inferred age of the Cheviot Hills Deposits may be older.

Cheviot Hills Deposits immediately below the basal older Benedict Canyon Wash Deposits erosion surface are ~500,000 years old (Figure 7) and represents soil marker horizon B (Figure 5; Plate ES-3). This is based on correlating dated soils in Borings CB-3 to CB-7 (LCI, 2012) to transect T-7 (Plate KGS-T7).

4.4 Age of the San Pedro Sequence (SPS)

The San Pedro Sequence (SPS) here refers to the "classic" marine San Pedro Formation (Qsp) and conformable overlying units that have similar structural histories. Based on the number of soil profiles and their development, ECI (2012) estimated that the San Pedro Formation is at least 600,000 years old. As ECI (2012) points out, the estimated age of San Pedro Formation of approximately 600,000 years is numerical, and may be 1,000,000 years old. 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.

Some soils in unit SPS above the San Pedro Formation and marker horizons Qfob and Qeb along Transect 4 (Plate ES-2a) are not recognized in the LCI (2012) borings evaluated by ECI (LCI CB-3; Plate ES-2b). Absent layers include marker beds E and F (Figure 5) that do not occur in Boring CB-3, most likely due to soil truncation or soil profiles combining laterally. These absent layers were not evaluated (dated) or included in the cumulative soil ages prepared for CB-3. This data suggest that the cumulative soil age of unit SPS in boring CB-3 reported in LCI (2012), ECI (2012) and Soil Tectonics (2012a, 2012b) may be substantially too young by tens of thousands if not hundreds of thousands of years.

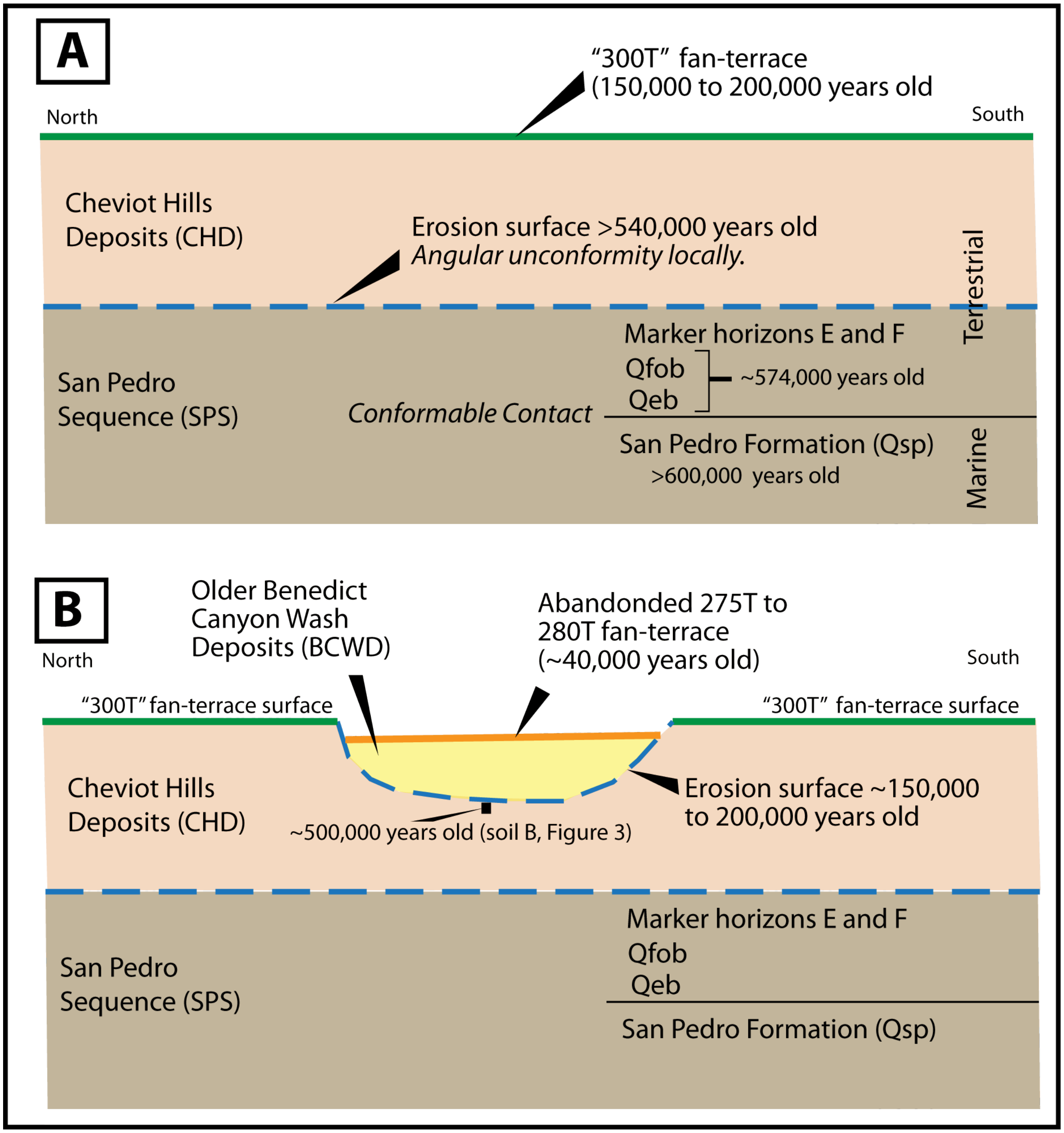
5.0 GENERALIZED LATE QUATERNARY EVOLUTION OF THE CHEVIOT HILLS

A general evolution of the Cheviot Hills (Century City) area since the late Pleistocene is illustrated in Figure 7. The diagrams illustrate specifically how older Benedict Canyon Wash Deposits are nestled with the Cheviot Hills. Also indicated are estimated ages of depositional and erosion events. The contact between the San Pedro Formation (Qsp) and overlying Qeb is conformable and represents a transitional contact for marine regression. The prominent erosion surface between SPS and overlying CHD may represent the onset of local folding and uplift in the region due to local fault systems.

Cheviot Hills Deposits placement ended approximately 150,000 to 200,000 years ago (Figure 7 Diagram A). The upper 300T fan-terrace surface was planar and not dissected. Between 150,000 to 200,000 years ago (Figure 7 Diagram B), erosion in the Cheviot Hills, likely associated with lower sea level that occurred during MIS-6, caused incision by an ancient Benedict Canyon Wash flowing southward through Century City (Plate ES-1b). The ancient wash was then filled with older Benedict Canyon Wash Deposits about 40,000 to 150,000 years ago. Approximately 40,000 years ago, the ancient channel of Benedict Canyon Wash was abandoned. As discussed later in this report, activity of the Santa Monica Boulevard

Fault Zone and local uplift deformed the 300T fan-terrace surface, which allowed for the ancient Benedict Canyon Wash to erode through the Cheviot Hills (stream capture).

Figure 7: Generalized evolution of the Cheviot Hills (Century City) since the late Pleistocene.



6.0 EVALUATION OF SUBSURFACE DATA

6.1 Evaluation Methodology

This study also evaluates new subsurface data from Parsons (2011) along Transects T1-8, T2-2E, T4, and T7, Parsons (2011) along Constellation Boulevard, and from LCI (2012), ECI (2012) and Soil Tectonics (2012a, 2012b). Most stratigraphic and structural evaluation focused on the Parsons (2011) boring log data.

6.1.1 Observing Geologic Contacts and Stratigraphy

Two approaches were used. The first involved interpreting and correlating geologic contacts and stratigraphy from boring to boring. This approach was applied to Transect 4 and along Constellation Blvd and the results are shown on Plates ES-8 and ES-9. Based on the geologic contacts and stratigraphy, combined with an assumption that units are dipping, the stratigraphic units and contacts correlate sufficiently well to preclude all of the Parsons (2011) inferred faulting associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone. An exception, however, may be a fault identified on the Constellation Blvd transect near the axis of the anticline (Plate ES-8).

The second approach is discussed in the following sections.

6.1.2 Processing Boring and CPT Data

The second approach identifies and evaluates fining upward sequences to identify soil marker horizons on Parsons (2011) boring data along Transects T1-8, T2-2E, T4 and T7. Fining upward sequences analysis works well along Transects T1-8, T2-2E, T4 and T7, with the results shown on Plates KGS-T1, KGS-T2, KGS-T4, and KGS-T7. Fining upward sequence analysis was not possible along Transects T3 and Constellation Blvd (Parsons, 2011) due to insufficient boring and CPT data. The Parsons boring information proved more insightful than the Parsons CPT data. 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. This inference could easily lead to the false identification of faults that are not actually present.

During this analysis, each Parsons (2011) boring log from Transects T1-8, T2-2E, T4 and T7 was spliced to visualize the entire log. In each log, layers were color coded 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. Poorly sorted units are identified by various colors; for example, clay silt has a thin orange line, a sand and gravel layer has a thin yellow and green lines, and so on. The Parsons (2011) boring logs provided an estimated percentage amount of gravel in specific layers even if the gravel content was as low as a trace or 5 percent.

6.1.3 Correlating oxide and carbonate deposits

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 (2012) boring logs for adjacent borings along the T4 Transect. Manganese oxide concentrations appear frequently on the Parsons logs.

Parsons (2011) logs also describe carbonate deposits by their morphology and abundance. This also proved useful in correlating marker horizons. The carbonates documented in the Parsons (2011) logs were correctly not assumed to be pedogenic. 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”.

The manganese oxide and carbonate deposits typically correlate to regionally extensive buried paleosols that can now be interpreted as datable stratigraphic markers. These particular stratigraphic markers are unbroken across many of the faults Parsons (2011) determined to be geomorphically reflected by the West Beverly Hills Lineament.

6.1.4 Interpretation of Argillic Horizon clay and shear surfaces

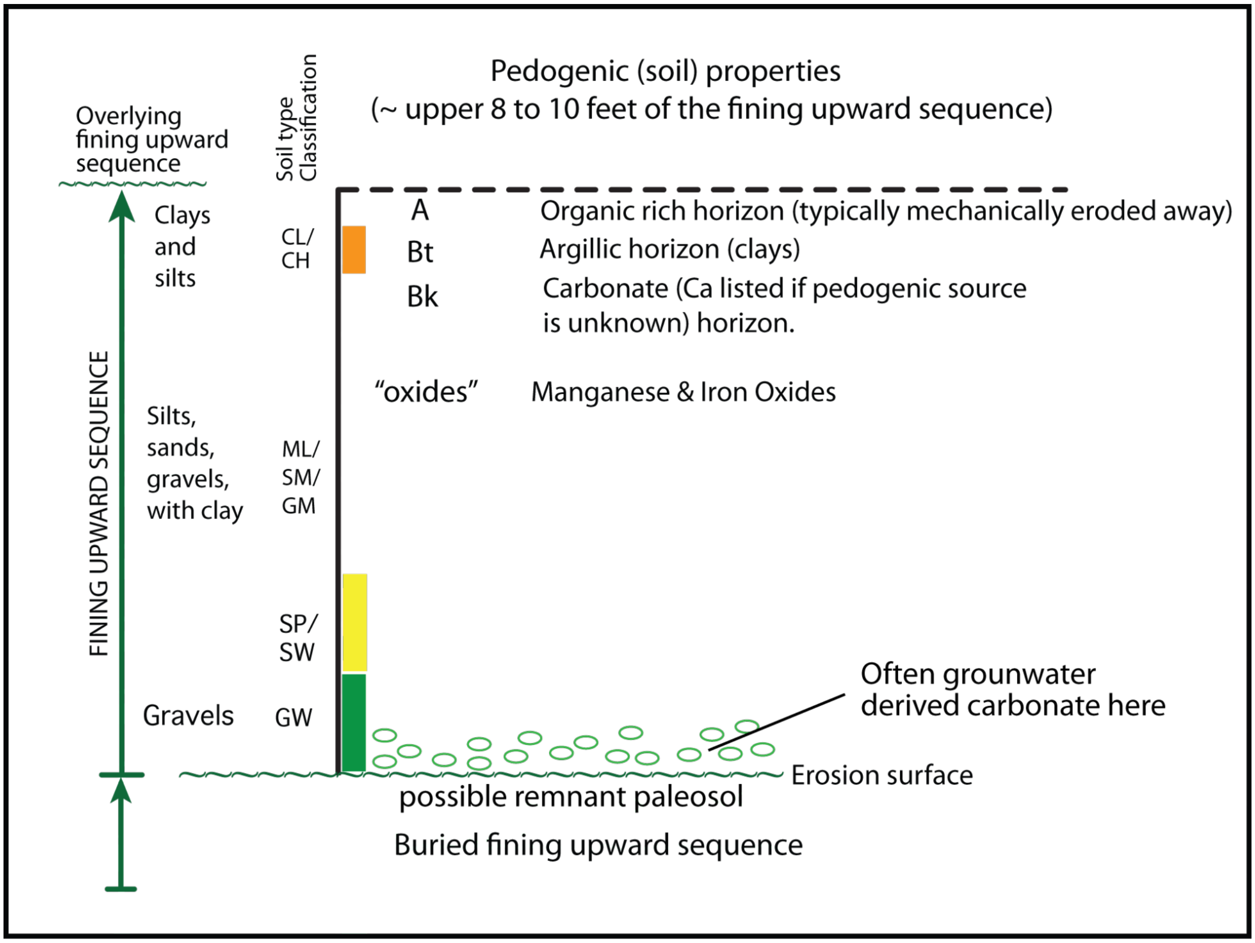
Parsons (2011) identified numerous “shear surfaces” in its boring logs and considered these shear surfaces tectonic in origin. The LCI (2012) trench exposures and continuous cores provided the opportunity to closely examine “shear surfaces” that Parsons (2011) would have identified as tectonic in nature. This examination 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. In essence, therefore, the Parsons evidence for local faulting in some instances is better explained by the pedogenic process.

6.1.5 Fining upward sequences

Based on direct examination of the LCI (2012) continuous cores and evaluation of the Parsons (2011) boring logs, almost the entire stratigraphic sequence reflects grossly fining upward sequences. Fining upward sequence analysis is suited to the Cheviot Hills area. For example, throughout California Mediterranean climate and vegetation regimes, epochs of lower base level are associated with regionally pluviality and channel incision. With the onset of more arid conditions, channels are filled, initially with coarse-grained sediments followed by sand and silt. Ultimately, during epochs of regional landscape stability (interglacial or inter-stadial) soils (pedogenic profiles) form. Eventually the process is repeated with onset of the next climatically controlled erosional and depositional cycle (Shlemon, 1972). The end product is often several grossly fining upward sequences that are reflections of regional climatic and vegetation change. Assemblages of fining upward sequences can be identified in the LCI (2012) trenches and cores, and from re-interpretation of the Parsons (2012) logs (Plates KGS-1, KGS-2, KGS-4 and KGS-7). The characteristics of a typical fining upward sequence are shown in Figure 8.

Soil characteristics of a fining upward sequence include the sequential change with depth of the A, Bt (argillic clay) and Bk (carbonate) horizons in addition to the increased abundance of oxides (manganese and iron) below the soil horizons (Figure 8). This sequence with depth is a function of their solubility. For example, translocated clay is the least soluble and manganese oxide is the most soluble and thus extend to the deepest depths in the soil profile. Multiple “k” horizons (carbonates) often occur and indicate a climatic change. Rarely are the A horizons preserved in pre-Holocene age soils due to chemical weathering (oxidation) or mechanical weathering (erosion). 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.

Figure 8: General Characteristics of a Fining Upward Sequence.

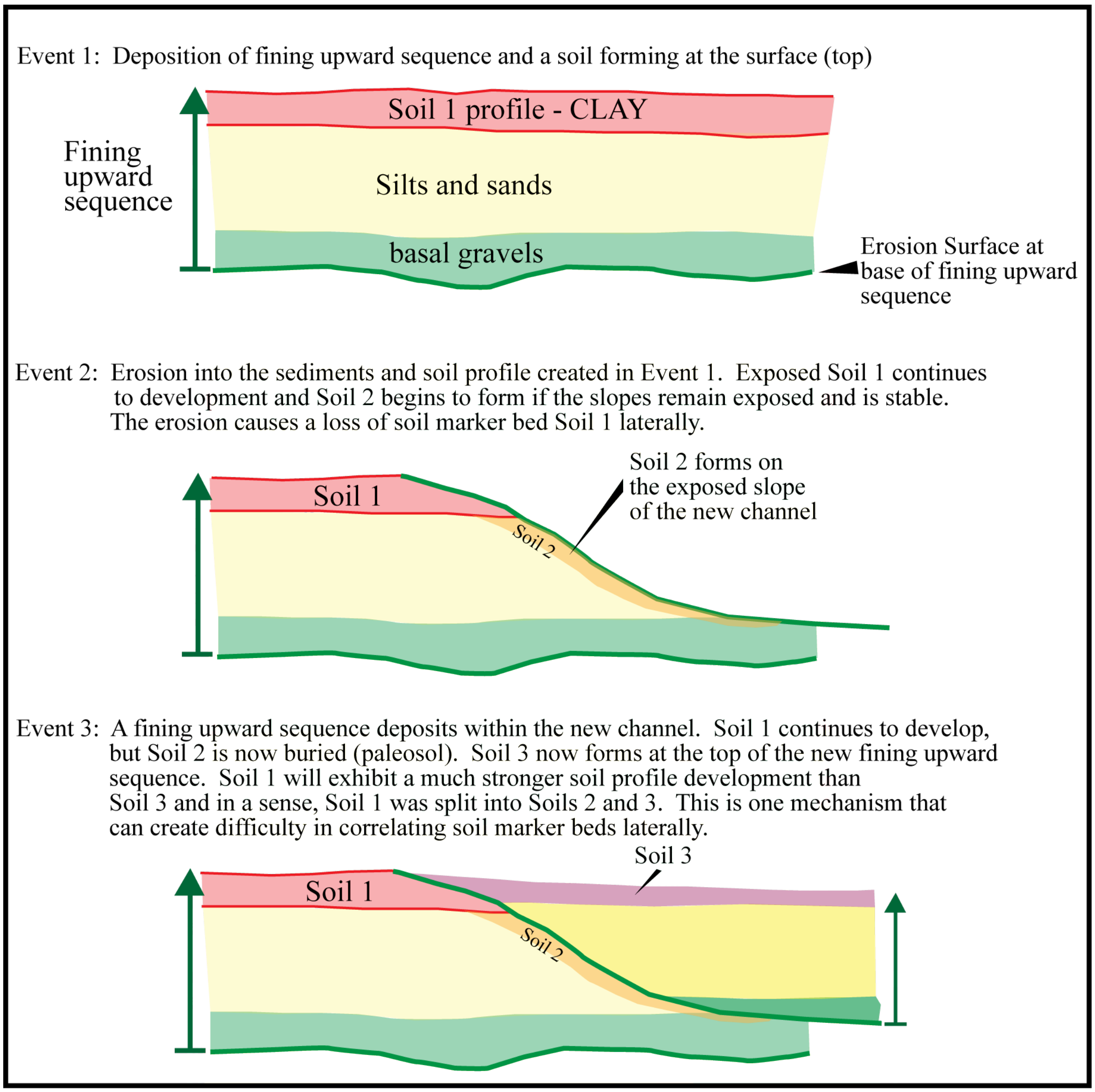


An indication of faulting was the apparent offset of soil horizons and contacts and disruption of fining upward sequences. Within the Santa Monica Boulevard Fault Zone on transects shown on Plates KGS-T1 and KGS-T2, fining upward sequences were typically disrupted and less obvious partially due to local vertical displacements that affected local erosion and deposition. Tectonics is a local factor that may exceed the impact of climatically controlled deposition and erosion within these zones. Accordingly the correlation of geologic contacts (BCWD, CHD, and SPS) and soil marker horizons in a fault zone are tentative. The vertical resolution of subsurface markers was qualitatively determined to range from about three to five feet. Hence, faults with this range of vertical displacement (separation) or less would be difficult to identify with the available data resolution. In addition, identified faults may extend to shallower depths than indicated on the transect cross section (Plates KGS-T1, -T2, -T4 and –T7) if they exhibit offsets equal to or less than 3 to 5 feet. 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.

6.1.6 Marker beds and evolving soil profiles

Basal channel erosion surfaces are usually undulatory and are often steep, especially along their banks. Additionally, depending on stream power, they commonly erode away older underlying sediments, including pedogenic and other marker beds and can dip at fairly steep angles, thus suggesting fault presence where none exist (Figure 9). This is illustrated on Transect 4 (Plate KGS-T4) between Parsons (2011) CPT-T4-C1 and T4-C11. Here two channels have eroded a soil horizon at a depth of approximately 35 to 40 feet, which coincides with some Parsons (2011) proposed West Beverly Hills Lineament-Newport-Inglewood Fault Zone faults.

Figure 9: Example of soil development across an evolving landscape.



Many marker beds in the Parsons (2011) report and this study are soil profiles that formed on a geomorphic stable surface; however, landscapes constantly evolve over time. As shown in Figure 9, 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 between the borings. This is well exemplified on Transect T2-2E (Plate KGS-T2) near Parsons (2011) CPT T2E-C8 at a depth of 32 feet.

6.1.7 Folding

Another potential misinterpretation for fault presence stems from folded beds. Plate ES-8 reinterprets the Parsons (2011) Constellation transect, which shows beds tilted to the northeast. 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 (Plate ES-15). Parsons (2011) assumed these units were absolutely horizontal, and hence that faults are present. Also, the Parsons cross-section greatly exaggerates apparent soil layer discontinuity, with a vertical scale 10 times greater than the horizontal. This inherently gives the impression of large vertical discontinuity between the boring and CPT subsurface data. Plate ES-14 shows the Constellation Boulevard cross section with no vertical exaggeration. This northeastern fold is also identified in Transects 2-2E and 4 (Plates KGS-T2 and KGS-T4) as an anticline and monocline that parallels the West Beverly Hills Lineament in the Cheviot Hills (Plates ES-4, ES-11 and ES-18).

6.2 Results of Alternative Evaluation of Parsons Transects

In light of the above, Kenney GeoScience re-interpreted the Parsons (2011) transect data specifically focused on basal erosion surfaces, soil forming processes across an evolving landscape, and folding (tilting of beds due to deformation). The Kenney GeoScience evaluation of the Parsons (2011) transects T1-8, T2-2E, T4 and T7 and along Constellation Boulevard indicates that the Parsons (2011) proposed north-northwest trending extension of the Newport-Inglewood Fault Zone within the West Beverly Hills Lineament does not exist in Century City.

There are faults within the Parsons (2011) proposed West Beverly Hills Lineament-Newport-Inglewood Fault Zone, but these faults are part of the northeast to southwest trending Santa Monica Boulevard Fault Zone (Faults F1 and F2 shown on Plate ES-2b). The subsurface data acquired by Parson (2011) does not provide any fault strike data, thus it is difficult to evaluate the trend of any of the faults in the study area. Determining fault strike with the existing data requires correlating fault dip, and sense of apparent displacement between transects. In other words, if faults are identified in two transects exhibiting the same dip direction and the same sense and magnitude of slip (i.e. normal) then it supports the conclusion that they are the same fault. This is the case for Faults F, F1 and F2 identified on Transects T1-8 and T7 (Plates KGS-T1 and KGS-T7), which are considered herein to be part of the same fault zone. In addition Faults F1 and F2 were not identified by Kenney GeoScience within Transect 4 suggesting that these faults trend more toward the northeast such that they do not encounter Transect 4.

Fault F was originally identified by MACTEC (2010) at the same location as Parsons (2011) along Transects 1-8 and 3 (Plate ES-10). However, Parsons (2011) project this fault in a straight line and terminated it prior to Transect 7, north of Transect 4 (Plate ES-10). This fault may exist and is referred herein as Fault F1. MACTEC (2010) identified a fault directly on trend where Kenney GeoScience identified Fault F2 in Transect T7 immediately south of Transect 4 (Plate KGS-T7 and Plate ES-10). Accordingly, Kenney GeoScience judges that all faults identified and currently yet to be identified in the Century City area are likely associated with upper plate deformation of the Santa Monica Fault Zone which includes the Santa Monica Boulevard Fault Zone and associated secondary cross faults (Plate ES-16).

Kenney GeoScience identified several discrete faults within the Santa Monica Boulevard Fault Zone: Faults A, B, C, D1, D2, E1, E2, F, F1 and F2 (Plate ES-2b). None of these faults reach the surface; however D1 extends to a depth of ~13 feet. Faults A, B, D1, D2, E1 and E2, and possibly F extend upward into the older Benedict Canyon Wash Deposits which are a minimum of 40,000 years old (fan-terrace 275T). These faults rose to within approximately 15 to 37 feet of the surface, suggesting that the Santa Monica Boulevard Fault Zone faults have not ruptured the surface in the past 40,000 years, and hence are “ not active” according to State of California fault rupture laws (Hart and Bryant, 2007). These faults are discussed in more detail later in the report.

7.0 GEOMORPHIC EVALUATION OF THE CHEVIOT HILLS

A geomorphic analysis of the Cheviot Hills provides information about fault location, local folding, and relative age of surfaces. The topographic map used for the analysis is from Hoots (1931) and with 5-foot contours and produced prior to dense urbanization. The Hoots (1931) map portrays the geology of the Santa Monica Mountains area, extending from the Pacific Ocean on the west to the Los Angeles River on the east.

7.1 Evaluation of the Santa Monica Boulevard Lineament (SMBL).

The Santa Monica Boulevard Lineament (SMBL) is geomorphically expressed by a linear swale through which a railroad was constructed (Plate ES-1b). This later became the location of the modern Santa Monica Boulevard. Thus, by 1931, the Santa Monica Boulevard Lineament had already been altered. The Santa Monica Boulevard Lineament is linear, and assuming a fault origin, suggests that most slip is lateral.

7.2 Geomorphic Abandoned Fan-Terrace Surfaces

Plate ES-4 illustrates modern and abandoned fan-terraces within the Cheviot Hills. Prior to uplift, the surfaces (dark green areas) were all connected similar to the planar fan surface east of the Cheviot Hills (Plate ES-4). These surfaces are now deeply eroded to a depth consistent with incision over hundreds of thousands of years, but likely less than mid-Quaternary (Dohrenwend et al., 1991). Most of these relatively deeply incised areas expose Cheviot Hills Deposits and the preserved fan-terraces represent cessation of Cheviot Hills Deposits. An exception is the upper surface of the older Benedict Canyon Wash deposits, an estimated 40,000 years old (Plate ES- 1b).

The geomorphic fan-terrace map (Plate ES-4) shows elevations of the preserved surfaces by medium green lines. The contours change dramatically across Santa Monica Boulevard suggesting that these two geomorphic areas have experienced different deformation since at least cessation of deposition of the

Cheviot Hills Deposits. North of Santa Monica Boulevard, the contours are typical of alluvial fan surfaces, suggesting that this area has not been deformed internally but may have been uplifted collectively. There are however, two exceptions. The first exception is in the southwest Cheviot Hills between Ohio Street and Santa Monica Boulevard (Plate ES-4). Here the fan-terraces are markedly lower and may represent a younger inset surface or possibly faulting near the 300-foot contour line (Plate ES-13). The second exception is to the north where the contours widen on strike with the projection of the Hollywood Fault Zone to the east (Plate ES-4). This is consistent with the Hollywood fault possibly extending west of the West Beverly Hills Lineament and under the northern Cheviot Hills as a blind fault that does not reach the surface (Plate ES-18). Crook and Proctor (1992) similarly continue the Hollywood fault zone westward to the Pacific Ocean.

South of Santa Monica Boulevard, some extrapolated contours are closed. The closed contours parallel the West Beverly Hills Lineament and are believed to be the topographic expression of an anticline that strikes parallel to the West Beverly Hills Lineament (Plates ES-4, ES-13, ES-14, and ES-15).

The geomorphic terrace analysis map (Plate ES-4) also shows relatively low topography at the site of the proposed Santa Monica subway station. This surface is part of the 275T fan-terrace that narrows toward the southwest. This surface identifies the abandoned channel of an ancient Benedict Canyon Wash now filled with older Benedict Canyon Wash Deposits (Plate ES-1b).

7.3 The Santa Monica Boulevard Lineament Scarps

Dolan and Sieh (1992) and Dolan et al. (2000) proposed that scarps along Santa Monica Boulevard in Century City ranging in height from 7- to 12-meters (~23 to 40 feet) owe their origin to reverse faulting associated with the Santa Monica Fault Zone. Herein, fault scarps located between the Mormon Temple and the Los Angeles Country Club in Century City are considered part of the Santa Monica Boulevard Fault Zone (Figures 2 and 3). To test the hypothesis whether or not the Santa Monica Boulevard Fault Zone had experienced numerous reverse displacements during the past 150,000 to 200,000 years (age of surface sediments of the Cheviot Hills Deposits that are deformed by faulting), Kenney GeoScience (2011) constructed two cross sections across the Santa Monica Boulevard Fault Zone (Plate ES-4). Cross-section A-A’ and B-B’ are shown on Plates ES-5 and ES-6.

Cross-section A-A’ suggests that the 315T and 300T fan-terrace surfaces developed in Cheviot Hills Deposits correlate across the Santa Monica Boulevard Fault Zone and thus were once the same surface. To test this hypothesis, soil development on the 315T fan-terrace on Wilshire Boulevard (Plate 1a) was compared to soil development exposed at the Beverly Hills High School in LCI (2012) fault trench FT-1 at an elevation of 285 feet (Soil Tectonics, 2012a). These fan-terraces bear similar soil development and likely correlate (Soil Tectonics, 2012a). Cross section A-A’ indicates that no reverse scarp occurs across the Santa Monica Boulevard Fault Zone based on the continuity of the 315T and 300T fan-terrace. Hence, the scarp of Dolan and Sieh (1992) does not show reverse displacement, and certainly has not experienced 20 to 40 feet of vertical reverse apparent displacement. Accordingly, the Santa Monica Boulevard Fault Zone, which does exist, likely experienced primarily strike-slip motion.

Cross section B-B’ (Plate ES-6) shows similar correlated fan-terraces across the Santa Monica Boulevard Fault Zone where a topographic escarpment of these surfaces show probable normal apparent displacement (north side down) for north-dipping faults. The apparent normal displacement could result from lateral motion that places fan-terraces surfaces of varying heights juxtaposed across the Santa Monica Boulevard Fault Zone.

The geologic constructions on cross sections A-A' and B-B' indicate that the Santa Monica Boulevard Fault Zone is not a reverse fault system as proposed by Dolan and Sieh (1992). This observation, in addition to other findings in this report, suggests that the Santa Monica Boulevard Fault Zone may not be the basal left-lateral reverse Santa Monica Fault Zone proposed by Dolan and Sieh (1992) and Dolan et al., (2000). The observation that this fault zone is not dominantly reverse partly motivated the revised designation of the Santa Monica Boulevard Fault Zone (Figure 3). In addition, these findings provide supportive evidence that the Santa Monica Boulevard Fault Zone may be a secondary upper plate fault zone associate with the Santa Monica Fault Zone (see Figure 3) and its primary displacement is strike-slip (Plate ES-16). These conclusions are discussed in more detail later in the report.

7.4 Drainage Analysis of the Cheviot Hills

Drainage channels within the Cheviot Hills are shown on diagram A of Plate ES-7a. Diagram B (Plate ES-7b) shows drainages without base map data thus highlighting possible fault-offset drainage patterns. Diagram C (Plate ES-7b) shows drainages and Santa Monica Blvd, which essentially coincides with the Santa Monica Boulevard Fault Zone.

Most of the drainages crossing the Santa Monica Boulevard Fault Zone are not deflected. However two channels labeled A and B are apparently deflected right-laterally where they cross the Santa Monica Boulevard Fault Zone. These drainages assist in the identification of the topographic Santa Monica Boulevard Lineament. Drainage A suggests right-lateral fault displacement because it turns at a location where it intersects a small hill on the south side of the Santa Monica Boulevard Lineament. Drainage B turns and flows parallel to the Santa Monica Boulevard Fault Zone in a right-lateral sense of displacement as well but this may be due to artificial fill associated with railroad construction. Nevertheless, in the area a low order channel parallel to the trend of the Santa Monica Boulevard Lineament swale suggests the Santa Monica Boulevard Lineament geomorphic expression is partly due to erosion and not solely to fault displacements.

A couple of "hooked" drainages occur in the eastern Cheviot Hills labeled C on diagram C of Plate ES-7b. The "hooked" drainages are atypical of the drainage pattern observed throughout the Cheviot Hills and atypical to natural fan systems suggesting a tectonic origin. Although this report does not believe that north-northwest trending right-lateral faults associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone occur in this area as proposed by Parsons (2012), these types of faults could produce the "hook" drainage patterns. However, based on all the data presented in this report, it seems more likely that the "hooked" drainages result from folding, which is discussed later in the report.

8.0 SENSE OF SLIP ON THE SANTA MONICA BOULEVARD FAULT ZONE

The geomorphic lineament along Santa Monica Boulevard (SMBL) and lack of apparent vertical separation of fan-terraces across the Santa Monica Boulevard Fault Zone suggests that the Santa Monica Boulevard Fault Zone likely accommodates primarily strike-slip displacement from the Mormon Temple to the Avenue of the Stars (Plate ES-1b). In addition, the drainage analysis (section 7.4) indicates that the Santa Monica Boulevard Fault Zone has not experienced dominantly reverse motion (Plates ES-5 and ES-6). These data indicate that the Santa Monica Boulevard Fault Zone is dominantly right-lateral strike-slip.

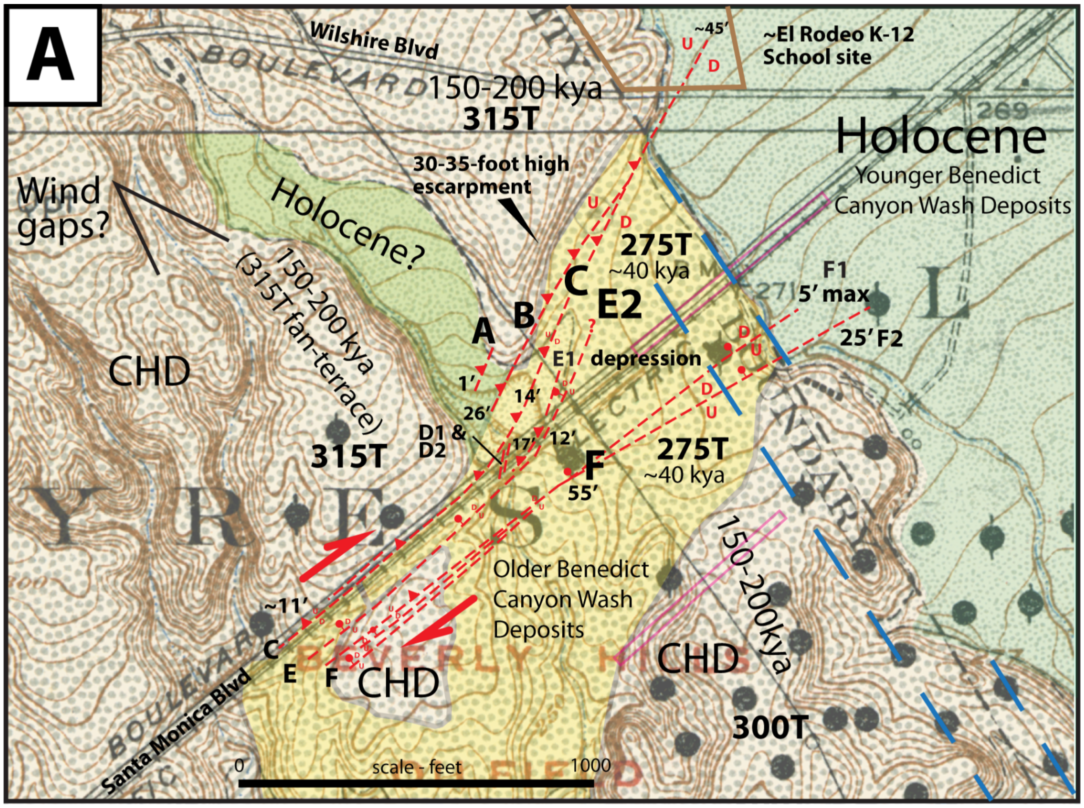
Most east-west trending faults in southern California have a left-lateral component of slip, as proposed by Dolan and Sieh (1992) for the Santa Monica Fault Zone (SMFZ). Based on data evaluated in this report, it appears that the Santa Monica Boulevard Fault Zone (SMBFZ; Figure 3) has mainly right-lateral displacement with local secondary normal and reverse offsets to the east. The strike of the Santa Monica Boulevard Fault Zone produces a local releasing bend relative to the general trend of the Santa Monica Fault Zone west of Century City (Plate ES-17), which provides a mechanism for the component of normal displacement observed along the Santa Monica Boulevard Fault Zone in Century City (Plates ES-2b and KGS-T2). Additionally, strike-slip faults typically splay into areas of uplift and down-dropping in regions of their termination. This occurs in the study area (Plate ES-2b and Figure 10) as indicated by geomorphic relations and style of apparent vertical separations identified in cross sections (Plates KGS-T1, -T2, -T4 and –T7).

Figure 10 shows the surface geology, local faults style and magnitude of apparent displacement, and local topography. The apparent vertical separation of these faults is based on displacement of the top of the San Pedro Formation (Plates KGS-T1, -T2, -T4 and –T7). A prominent local geomorphic structure is a 30 to 35-foot high escarpment immediately northwest of Faults B and C. Dolan and Sieh (1992) interpreted this as the eastern most reverse scarp associated with the Santa Monica Fault Zone (Figure 3). This escarpment has probably been modified by lateral erosion of the ancient Benedict Canyon Wash and has also formed by local fault displacements. A second prominent geomorphic feature is a depression southeast of the 30 to 35-foot high escarpment marking a fan-terrace surface (~275T surface) associated with the older Benedict Canyon Wash Deposits. The surface soil on this fan-terrace is estimated to be 40,000 years old.

Faults A, B, C and E1 show reverse vertical separation at the top of the San Pedro Formation (Figure 10, Plates KGS-T1 and –T2). These faults are identified by the red, north-dipping triangular barbs on Figure 10 (also see Plate ES-2b). The cumulative reverse vertical separation across these faults is approximately 58-feet, sufficient to produce the 30 to 35-foot high reverse scarp. However, faults E2 and F dip north with normal vertical separation of 67-feet and contributed to produce the depression in which the ancient Benedict Canyon Wash flowed through the Cheviot Hills approximately 40,000 to 150,000 years ago (possibly as old as 200,000 years ago; Plate ES-16). Slip across Faults A through F has both normal and reverse separations, indicating that the Santa Monica Boulevard Fault Zone accommodated strike-slip movement. Also, Fault F changes from apparent normal displacement in the northeast, to apparent reverse in the southwest, suggesting that the fault has strike-slip displacement. In summary, the Century City faults (Santa Monica Boulevard Fault Zone) have not been subject to major reverse slip, but rather to primarily strike-slip displacement. Local escarpments and depressions in this region mimic fault apparent vertical separations east of the Avenue of the Stars and are consistent with right-lateral motion across the Santa Monica Boulevard Fault Zone (Plate ES-2b).

Right-lateral displacement across Faults A, B, C and E1 northeast of the Avenue of the Stars (Plate ES-2b) have a local restraining bend orientation that produced the 30 to 35-foot high escarpment. Faults E2, F1 and F2 exhibit apparent normal separations due to the releasing bend orientation of the Santa Monica Boulevard Fault Zone to the Santa Monica Fault Zone and their orientation relative to the right-lateral primary displacement of the Santa Monica Boulevard Fault Zone. Faults F1 and F2 have a releasing bend orientation within the right-lateral dominated Santa Monica Boulevard Fault Zone. In summary, alternating compression and extension across faults of varying strike within the eastern Santa Monica Boulevard Fault Zone are typical of terminating strike-slip movement. In this conceptual model, right-

Figure 10: The surface geology (diagram A) and topographic map of Hoots (1931; diagram B) of the Century City area. Diagram A illustrates the approximate extent and ages of surface sediments and fan-terraces in the Century City area. The three exposed geologic units are the Holocene modern Benedict Canyon Wash Deposits (green), the older Benedict Canyon Wash Deposits (yellow) and the Cheviot Hills Deposits (CHD). Approximate locations of the proposed Metro Santa Monica Blvd and Constellation subway stations are shown as pink rectangles. Faults are shown as thin dashed red lines and labeled A, B, C, D1, D2, E1, E2 and F. Faults with triangular barbs have apparent reverse slip separation; and faults with circular barbs have apparent normal vertical separation. The amount of vertical displacement is shown in feet as measured from the top of the San Pedro Formation. The dashed blue lines are two proposed faults associated with the West Beverly Hills Lineament Fault Zone by Parsons (2012). See text for details.


A
Wilshire Blvd
BOULEVARD
150-200 kya
315T
~45'
U
D
~El Rodeo K-12
School site
Holocene
Younger Benedict
Canyon Wash Deposits
30-35-foot high
escarpment
Wind
gaps?
Holocene?
150-200 kya
(315T fan-terrace)
CHD
275T
~40 kya
C
E2
B
A
F1
5' max
25' F2
E1
depression
1'
14'
26'
D1 &
D2
17'
12'
315T
F
55'
275T
~40 kya
Y R E S
Older Benedict
Canyon Wash
Deposits
150-200kya
~11'
C
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F
CHD
CHD
300T
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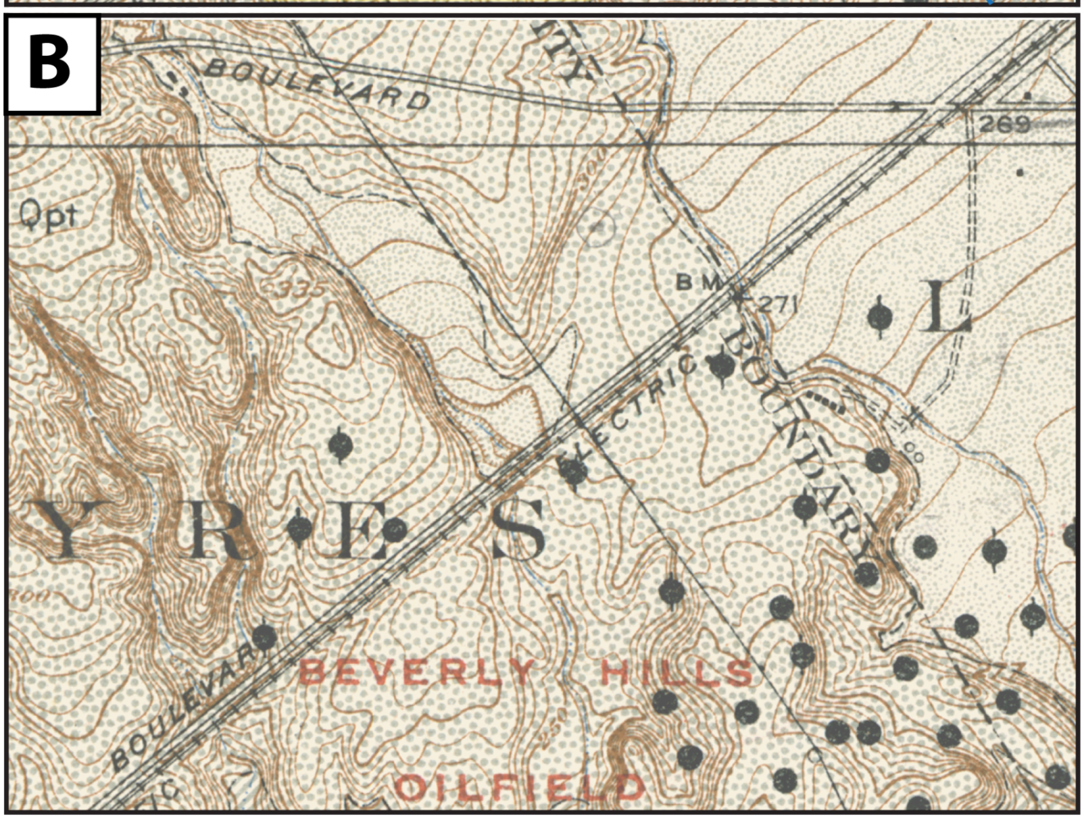
B
BOULEVARD
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BOULEVARD
BEVERLY HILLS
OILFIELD

lateral motion causes compression across northeast-trending Faults A, B, C, and E1. The 30 to 35-foot escarpment was thus produced by local restraining bend compression, scarp erosion by ancient Benedict Canyon Wash, and normal apparent separations of faults E2, F1 and F2.

If the Santa Monica Boulevard Fault Zone is dominantly right-lateral with local normal and reverse slip, then it is most likely not the oblique left-lateral reverse Santa Monica Fault Zone postulated by Dolan and Sieh (1992). Rather, the proposed right-lateral style of displacement across the Santa Monica Boulevard Fault Zone is consistent with this fault zone as an upper plate fault to the Santa Monica Fault Zone (Figure 3). If this concept is correct, then the Santa Monica Fault Zone is south of the Santa Monica Boulevard Fault Zone within the southern Cheviot Hills (Plate ES-12).

9.0 IS THE SANTA MONICA BOULEVARD FAULT ZONE A SECONDARY UPPER PLATE FAULT?

As suggested here, the Santa Monica Boulevard Fault Zone consists of faults that extend approximately 1.7 miles sub-parallel to the geomorphic lineament/scarp along Santa Monica Boulevard between the Mormon Temple on the west and near the West Beverly Hills Lineament in the east (Figure 3). The Santa Monica Boulevard Fault Zone ostensibly branches from the primary basal Santa Monica Fault Zone at a bend in the Santa Monica Fault Zone near the Mormon Temple (Plate ES-4). As proposed earlier, the Santa Monica Boulevard Fault Zone is dominantly right-lateral and produces alternating areas of uplift and depression within the zone due to fault orientations and fault zone splaying. Hence, the Santa Monica Boulevard Fault Zone may be an upper plate fault, a component of the Santa Monica Fault Zone, which was identified by numerous studies at the West Los Angeles Veterans Administration Hospital 1 to 2 miles west of Century City (Pratt et al., 1998; Dolan and Pratt, 1997; Dolan et al., 2000; Catchings et al., 2008; Catchings et al., 2010). This hypothesis is also supported by structural relationships between secondary upper plate faults and the basal reverse fault associated with recorded fault surface rupture deformation, which is discussed below.

9.1 Primary and secondary structures associated with oblique left-lateral reverse faults

Surface fault rupture deformation caused by the El Asnam Earthquake of October 10, 1980 was documented by Phillip and Meghraoui (1980). This was an oblique left-lateral reverse fault rupture, the same motion as proposed for the Santa Monica Fault Zone. Plate ES-1, modified from Figure 17 of Phillip and Meghraoui (1980), shows surface rupture structures of basal primary reverse faults (red barbs) and upper plate secondary faults (gray lines). This map shows that the secondary faults have oblique, normal, right-lateral strike-slip displacement, consistent with the style of faulting proposed herein for the Santa Monica Boulevard Fault Zone. The angles between the secondary and primary reverse fault averages 34 degrees (Plate ES-11). As shown on Plate ES-12 for the Santa Monica Fault Zone, the angle between the Santa Monica Boulevard Fault Zone and the general trend of the Santa Monica Fault Zone is approximately 24 degrees, and the angle between the Santa Monica Boulevard Fault Zone and the postulated location of the blind basal Santa Monica Fault Zone in the Cheviot Hills is approximately 35 degrees (Plate ES-12). These two values average 30 degrees. Thus, the Santa Monica Boulevard Fault Zone appears to be at an angle to the basal primary Santa Monica Fault Zone in a similar relative orientation as secondary faults demonstrated by Phillip and Maghraoui (1980) across an oblique left-lateral reverse fault.

9.2 Comparison of SMFZ and SMBFZ Dip

The dip of the basal Santa Monica Fault Zone, measured at the Veterans Administration Hospital grounds approximately 1 to 2 miles west of Century City is north 20 to 30 degrees (Pratt et al., 1998; Catchings et al., 2008; Plate ES-12). However, the Santa Monica Boulevard Fault Zone in Century City dips 50 to 80 degrees north (MACTEC, 2010; Parsons, 2011). Secondary faults generally dip at much higher angles than the basal primary reverse fault (Plate ES-12). This suggests that the Santa Monica Boulevard Fault Zone may be a zone of secondary upper plate faults and that the basal reverse fault of the Santa Monica Fault Zone underlies the southern Cheviot Hills.

10.0 LATE QUATERNARY FOLDING IN THE CHEVIOT HILLS

The geomorphic map of the Cheviot Hills shows contour lines across abandoned fan-terrace surfaces (thick relatively dark green lines) and closed contours suggesting that the Cheviot Hills south of Santa Monica Boulevard are an antiformal structure (Plate ES-13). The eastern fold limb may extend across the West Beverly Hills Lineament (current Benedict Canyon Wash) into low-lying hills east of the West Beverly Hills Lineament (Plate ES-1b).

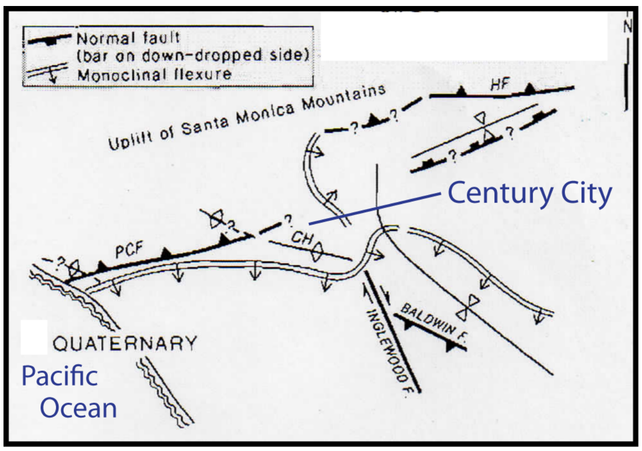
The Constellation Boulevard cross section (Plate ES-14) shows anticlinal folding in the Cheviot Hills Deposits (CHD) and San Pedro Sequence (SPS). This mimics the current land surface, suggesting that folding in the Southern Cheviot Hills has taken place since abandonment of the 300T fan-terrace the past 80,000 to 200,000 years ago. The anticlinal axis is identified at the intersection of the Avenue of the Stars and Constellation Boulevard (Plates ES-14 and ES-15). This anticline was also identified by Parsons (2012), based on their structure contour map of the top of the San Pedro Formation, with the fold axis near the proposed Constellation subway station.

Tilted Cheviot Hills Deposits and San Pedro Sequence are identified in Transects T1-8, T2-2E, T4 and T7 (Plates KGS-T1, -T2, -T4 and –T7) and in the Parsons (2011) Transect T3. Plate ES-15 shows the approximate dip of the upper San Pedro Formation (Qsp) along the various transects and the axis of the anticline near the Avenue of the Stars and Constellation Boulevard intersection. Plate ES-15 also illustrates fold-limb dips, which are approximately 1.0 to 1.3 degrees near the axis. The fold apparently plunges north at approximately 1.5 degrees. This fold, based on the cross section interpretation, also deforms the overlying Cheviot Hills Deposits.

A subtle fold involves the San Pedro Sequence and possibly lower members of the Cheviot Hills Deposits. This fold occurs on the eastern limb of the anticline, strikes parallel to the anticline, and increases dip of the upper San Pedro Sequence. Its form suggests a monocline fold within the eastern limb of the anticline (Plate ES-15).

The anticlinal and monoclinal folds generally parallel the West Beverly Hills Lineament and may well explain development of the West Beverly Hills Lineament. The folds show that since the late Pleistocene, the Cheviot Hills south of Santa Monica Boulevard have been uplifted along a north-south axis parallel to the West Beverly Hills Lineament. Sediments east of the West Beverly Hills Lineament (and Cheviot Hills) are lower and on-going erosion by Benedict Canyon Wash during uplift produced the West Beverly Hills Lineament and its escarpment. Benedict Canyon Wash has sufficient stream power to erode the Cheviot Hills during uplift indicating that the wash is antecedent to uplift. This model suggests that folding occurs north of Santa Monica Boulevard although there is a paucity of subsurface data in that region. However, the concept of folding occurring north of Santa Monica Boulevard is supported by the geomorphology of the West Beverly Hills Lineament in this area. The 300T fan-terraces, although elevated north of Santa Monica Boulevard, do not appear to be antiformally deformed (Plate ES-4). However, Wright (1991) does show an east-dipping monocline along the trend of the West Beverly Hills Lineament immediately south of the Hollywood fault zone (Figure 11).

Figure 11: Sketch map by Wright (1991, Figure 16) of the general tectonic behavior of the Santa Monica (Wright's Potrero Canyon Fault-PCF), Hollywood, and Inglewood fault zones and deformation associated with their intersection during the past 2 million years (Quaternary). See text for details.



An inferred late Pleistocene uplift of the anticline is estimated at the top of the San Pedro Formation of approximately 12.2 meters (~40 feet; Plate ES-14). This suggests an uplift (folding) rate of approximately 0.02 mm/year, assuming that the San Pedro Formation is 600,000 years old (ECI, 2012). The late Pleistocene tilt rate is inherently low based on a dip of 1.5-degrees during the past 600,000 years.

11.0 PROPOSED WEST BEVERLY HILLS LINEAMENT-NEWPORT-INGLEWOOD FAULT ZONE

The West Beverly Hills Lineament (WBHL) is a strong north-northwest striking geomorphic (topographic) lineament extending along the eastern side and through the Cheviot Hills (Plate ES-4). The Metro (2010) report summarizes the lack of understanding about origin of the West Beverly Hills Lineament:

"Various tectonic interpretations have been proposed for the WBHL. For example Dolan et al (1997) speculated that it may represent an east-dipping normal fault associated with extension along the left step between the Hollywood and Santa Monica faults. Others have speculated that the WBHL may be the northernmost of a series of en echelon, left-stepping, right-lateral strike-slip faults of the Newport Inglewood fault (Wright 1991, Dolan and Sieh, 1992, Hummon et al. 1994, Tsutsumi et al. 2001), or a fold scarp along the northern extension of the back limb of the gently east-dipping Compton blind thrust fault (Dolan et al. 1997). However Lang (1994) reported that subsurface

mapping within the Cheviot Hills and Beverly Hills oil fields, constrained by dense subsurface control, precludes the existence of the WBHL [as produced by a distinct fault]. *Thus the prospect that the WBHL is the surface manifestation of an active fault has not been confirmed (page 3-15)."*

Wright (1991) also shows a Quaternary monoclinal (fold) flexture near the West Beverly Hills Lineament (Figure 11). Parsons (2011) concluded, based on boring and CPT data that a fault zone of approximately 7 to 9 strands within a zone trending ~40 degrees northwest and approximately 600-feet wide occurs near the West Beverly Hills Lineament. They referred to this fault zone as the West Beverly Hills Lineament-Newport-Inglewood Fault Zone (WBHL-NIFZ). As mapped by Parsons (2011), the West Beverly Hills Lineament-Newport-Inglewood Fault Zone trends directly through the Beverly Hills High School (BHHS; Plate ES-2a). The Parsons (2011) study provided preliminary data regarding fault locations, but did not provide any age data to determine if the faults are active. The Parsons (2011) faults were based solely on interpretation of subsurface boring, CPT, and geophysical data, and hence did not depict strike. Such faults, therefore, if existing, could strike in almost any direction and inherently not conform to the West Beverly Hills Lineament.

Recently, LCI (2012) performed a detailed fault investigation study in the Beverly Hills High School involving borings, BPT, and fault trenching across the proposed Parsons (2011) West Beverly Hills Lineament-Newport-Inglewood Fault Zone. Kenney GeoScinece (Dr. Kenney) observed the trenches and examined cores collected during the LCI (2012) study. Their fault trenches covered approximately 90% of the Beverly Hills High School property. The LCI (2012) investigation also provided dates for near-surface sediments in the upper 150 to 200 feet (Figure 5) that shows the presence of demonstrably pre-Holocene sediments. Hence, an erosional, rather than a tectonic explanation is more appropriate to account for the origin of the West Beverly Hills Lineament. LCI (2012) identified two northwest-trending faults and a several northwest-trending hairline fractures that exhibited up to 1/2-inch down-to-the-west displacements. A soil microfabric study (LCI, 2012; Appendix B) on the hairline concluded that no shearing had occurred on these structures for tens of thousands of years. Hence, LCI (2012) determined that all of these displacement features are inactive. LCI (2012) concluded that hair-line offset structures were not tectonic but were caused by outward rotation of the east-side slope produced by Benedict Canyon Wash. Thus, regardless if the fractures were due to coseismic shaking deformation, or faulting, or paleoslope instabilities, they were all shown to be inactive. LCI (2012) thus concluded that the West Beverly Hills Lineament-Newport-Inglewood Fault Zone essentially does not exist in the near surface and that the local faults are probably secondary seismic structures not associated with a major fault zone.

Parsons (2012) responded to the LCI (2012) report by re-interpreting some of their proposed West Beverly Hills Lineament-Newport-Inglewood Fault Zone faults as "dying out" before they reached the LCI (2011) trench locations, or by shifting some fault trends in order to project through the few feet of gaps between the LCI trenches. These trench "gaps" only constitute about 10% of the Beverly Hills High School. Parsons (2012) also produced a subsurface structure contour map of the top of the San Pedro Formation, indicating that the westernmost fault (Parsons, 2011) of the West Beverly Hills Lineament-Newport-Inglewood Fault Zone exhibits approximately 300 feet of right-lateral displacement. The subsurface structure contour map also depicted the axis of a north trending and plunging anticline centered at the intersection of the Avenue of the Stars and Constellation Boulevard. Based on all of this data, it is currently not well understood whether the West Beverly Hills Lineament is a tectonic structure (fault or folding), an erosional feature of south flowing streams across an uplifting area, or a combination of these factors.

As mapped by Parsons (2011; 2012), the West Beverly Hills Lineament-Newport-Inglewood Fault Zone and Santa Monica Boulevard Fault Zone essentially merge near the proposed easternmost Santa Monica subway station (Plate ES-2a). However, as shown in this report, northwest-trending faults associated with the West Beverly Hills Lineament-Newport-Inglewood Fault Zone do not exist. Rather, northeast trending faults of the Santa Monica Boulevard Fault Zone that include at a minimum Faults F1 and F2 (Plate ES-2b) cross the area of the proposed West Beverly Hills Lineament-Newport-Inglewood Fault Zone identified by Parsons (2011). As shown on Plate ES-2b, Faults F2 and F1 may extend northeast from Transect 1-8 (Plate KGS-T1) to connect with Transect 7 (KGS-T7). Santa Monica Boulevard Fault Zone faults F and F2 (Plate ES-2b) were originally identified by MACTEC (2010). Kenney GeoScience agrees with that interpretation. MACTEC (2010) identified this northeast-trending fault at the same location as Parsons (2011) along Transects 3, and 1-8 (Plate ES-10). MACTEC's fault is informally designated as “Fault F”, which may bifurcate northeast to become Faults F1 and F2 (Plate ES-2b). If the southern most fault of MACTEC (2010) within the Santa Monica Boulevard Fault Zone is projected (Plate ES-10), it connects to the faults identified by Kenney GeoScience on Transect T7 (Plate KGS-T7). This is also the location of one West Beverly Hills Lineament-Newport-Inglewood Fault Zone fault depicted by Parsons (2011). The sense of slip and northward dip of Kenney GeoScience Faults F, F1 and F2 suggest this is a continuous fault zone. This interpretation is also supported by geomorphic expression of a local depression eventually filled by older Benedict Canyon Wash Deposits (Figure 10).

Other northeast trending faults may occur south of the F-F1-F2 fault zone, based on the ~5-degree dip of the upper San Pedro Formation contact along the southeastern extension of Transect 7 to LCI (2012) boring CB-7 (Plates ES-2b and ES-15). Parsons (2012) shows a “knob” in their subsurface contour map of the top of the San Pedro Formation (Parsons, 2012, Figure 2A; Plate KGS-2b) that may be associated with postulated northeast-trending faults located south of the F-F1-F2 fault zone. This postulated fault is shown on Plate ES-2b as a green dashed line extending through the southern Transect 7 extension area and Transects 3 and 1-8 of Parsons (2012).

In summary, there are deep faults in the region of the northwest-trending Parsons (2012) proposed West Beverly Hills Lineament-Newport-Inglewood Fault Zone; however, these faults are postulated to trend northeast as part of the Santa Monica Boulevard Fault Zone (Plate ES-2b). An evaluation of these faults' activity is provided in the next section.

12.0 ACTIVITY OF THE SANTA MONICA BOULEVARD FAULT ZONE

Two lines of evidence suggest that most, if not all of the faults in the Santa Monica Boulevard Fault Zone (SMBFZ) are not active according to the State of California. These lines of evidence include subsurface transect and geomorphic data. These are discussed in the next two subsections.

12.1 Subsurface Transect (Cross Section) Data

Faults by Parsons (2011) that trend sub-parallel to Santa Monica Boulevard (Plate ES-2a) closely correspond with those of this study herein referred to as the Santa Monica Boulevard Fault Zone (Plate ES-2b; Figure 3). Except for faults D1 and D2, we also agree that most of the faults within the Santa Monica Boulevard Fault Zone dip steeply northwest. There are however significant differences. First, we extend the southern-most Parsons (2011) fault along Santa Monica Boulevard, further northeast to connect with Transect 7 (Faults F, F1 and F2; Plate ES-2b). Second, Faults B and C (Plate ES-2b) are extended further northeast based on the postulated presence of fault(s) at the El Rodeo K-12 with north-side-up vertical offset (LCI, study in progress).

The Parsons (2011) cross-sectional data along transects T1-8, T2-2E, and T7 (Plates KGS-T1, -T2 and –T7) identified faults associated with the Santa Monica Boulevard Fault Zone designated as A, B, C, D1, D2, E1, E2, F, F1 and F2. Respectively, the surface projection of these faults is shown on Plate ES-2b. In general, soil marker beds do not readily correlate within the fault zones and fining upward sequences are often disrupted likewise indicative of faulting. In addition the region in the study area exhibiting the highest fault density located at the northwest end of Transect 1-8 and near its intersection with Transect 2-2E (Plates KGS-T1, KGS-T2 and ES-2b) is also where a south flowing drainage intersects with the ancient Benedict Canyon Wash (Plate ES-2b). The merging of the two drainage systems, local faulting, and colluvial processes associated with local channel margin slopes within Cheviot Hills Deposits likely disrupted local fining upward sequences and associated soil marker horizons during deposition of younger and older Benedict Canyon Wash Deposits in this area.

12.1.1 Fault A

Fault A is at the northwest end of Transect T1-8 (Plate KGS-T1) within a small south flowing drainage inside the Los Angeles Country Club property. Parsons (2011) extended Fault A to the surface within their older Alluvium of Pleistocene age (Plate ES-2a). As shown on Plate KGS-T1, the fault appears to offset San Pedro Sequence and Cheviot Hills Deposits. The apparent offset is reverse (1 to possibly 3 feet) but likely experienced more right-lateral slip based on marker bed separation across the fault. The upper offset Cheviot Hills Deposits beds are approximately 500,000 years old; penetration indicates that Fault A has been active since that time. Plate KGS-T1 shows that Fault A does not displace the base of the older Benedict Canyon Wash Deposits, which is an estimated 150,000 years to 200,000 years old. Further, one channel basal erosion surface in the lower Benedict Canyon Wash Deposits is not offset. This indicates that the last identifiable surface displacement of Fault A took place between about 150,000 to 200,000 years ago. The fault, by California definition, is therefore not active.

12.1.2 Fault B

Fault B occurs at the northwest end of Transect T1-8 and about 15 to 50 feet southeast of Fault A. Neither Kenney GeoScience nor Parsons (2011) identified this fault elsewhere. Parsons (2011) showed that Fault B does not offset Pleistocene fluvial deposits, and concluded that Fault B was inactive.

Kenney GeoScience analysis of Fault B shows that the last displacement probably took place after ~500,000 years ago. Based on un-faulted basal erosion surfaces within older Benedict Canyon Wash Deposits, which is an estimated 150,000 years to 200,000 years old, Fault B is inactive.

12.1.3 Fault C

Fault C is identified at the northwest end of Transect T1-8 approximately 90-feet southeast of Fault B (Plate KGS-T1), at the southwestern end of Transect 2-2E (Plate KGS-T2), and presumably in Transect T3 of Parsons (Parsons, 2011). This is also shown on Plate ES-2b. Parsons (2011) shows Fault C extending upward to within just a few feet of the surface on their Transects T1 and T3. Fault C dips northwest and generally exhibits approximately 13 to 14 feet of apparent reverse displacement of the upper contact of the San Pedro Formation. On Transects T-1 and T-2 (Plates KGS-T1 and KGS-T2), Fault C extends upward to within 38 and 25 feet of the surface respectively measured from the original surface (i.e. not including artificial fill). On Transect 2 (Plate KGS-T2) Fault C displaces the base of the Cheviot Hills Deposits by approximately 22 feet in an apparent reverse sense but does not offset overlying soil marker B within the Cheviot Hills Deposits estimated to be 500,000 years old. In Transect T1 (Plate KGS-T1), the base of the Cheviot Hills Deposits is not identified but members of the Cheviot Hills Deposits below soil marker horizon B are offset. Also in Transect T1, soil marker horizon B within the Cheviot Hills Deposits and immediately below the older Benedict Canyon Wash Deposits is either offset a few feet or gently folded. Fault C in Transects T1 and T2 does not offset the base of the older Benedict Canyon Wash Deposits estimated to be 150,000 to possibly 200,000 years old. These data indicate that Fault C offsets Cheviot Hills Deposits thus allowing it to assist in producing the Santa Monica Boulevard Lineament, but was inactive once erosion and deposition occurred associated with the older Benedict Canyon Wash Deposits. These data indicate that the Santa Monica Boulevard Lineament resulted from faulting, but that the scarp is a relict dominated by depositional and erosional processes and that Fault C is not active.

12.1.4 Faults D1 and D2

Faults D1 and D2 are shown on Transect 2 (Plate KGS-T2) and the Parsons (2011) report, but are not identified on nearby Transect T1-8. Faults D1 and D2 may be cross faults between Faults C and E1 that have a more northern trend and possibly dip southeast (Plate ES-2b). The dip direction of Faults D1 and D2 is unknown indicating that these faults may have exhibited either reverse of normal apparent vertical motion.

Collectively, Faults D1 and D2 exhibit approximately 33 feet of apparent dip-slip separation based on offset soil marker E within the San Pedro Sequence (Plate KGS-T2). Faults D1 and D2 likely formed after deposition of the San Pedro Sequence but possibly during deposition of the Cheviot Hills Deposits, which thins across this zone of faulting. Offset magnitudes of the base and upper members of the Cheviot Hills Deposits are uncertain. Faults D1 and D2 were active during deposition of Benedict Canyon Wash Deposits based on variations of unit thickness across Faults D1 and D2 collectively. No soil marker horizons overlie Fault D1; hence, the fault may have ruptured the surface of the older Benedict Canyon Wash Deposits estimated to be approximately 40,000 years old. However, an erosion surface associated with the Benedict Canyon Wash Deposits at a depth of approximately 22 feet on Transect T2 may connect undisturbed across Fault D1 (Plate KGS-T2). If this interpretation is true, then Fault D1 is not active.

Near faults D1 and D2 and Faults E1 and E2, the fining upward sequences within the Cheviot Hills Deposits and the older Benedict Canyon Wash Deposits are disrupted and eroded. As discussed earlier, the intersection of the two channels, faulting and colluvial soils derived from local slopes developed in Cheviot Hills Deposits likely affected the local development of fining upward sequences (Plate KGS-T2).

Faults D1 and D2 are considered cross faults within the Santa Monica Boulevard Fault Zone. Cross faults are common within faults zones. They generally exhibit variations in strike relative to the average trend of the major faults zone, and shorter lateral lengths because they physically connect with other faults in the system. Cross faults similar to Faults D1 and D2 may occur throughout the Santa Monica Boulevard Fault Zone particularly in the region bounded by Faults A and F.

12.1.5 Fault E1

Plate ES-2b shows the surface projection of Fault E1 cutting through Transects T2 and T1-8. The fault was not positively identified along Transect T3 to the southwest. Fault E1 was identified by Parsons (2011) to extend to a depth of approximate 45-feet (measured from the current surface with artificial fill) and not offset a member of their late Pleistocene older alluvium. Thus, Parsons (2011) indicated that this fault is not active. These findings are consistent with the evaluation herein as shown on Plate KGS-T2. Fault E1 is shown to terminate upwards below an erosion surface within members of the older Benedict Canyon Wash Deposits. As illustrated on Plates KGS-T1 and KGS-T2, Fault E1 was active during deposition of the older Benedict Canyon Wash Deposits but become inactive during continued deposition of the older Benedict Canyon Wash Deposits. Fault E1 offset the upper contact of the San Pedro Formation and base approximately 20 feet in an apparent reverse sense. The base of the older Benedict Canyon Wash Deposits may be offset by a reverse apparent displacement by approximately 31 feet, but this estimate is in question due to difficulties in evaluating the true limits of the lower contact of the Benedict Canyon Wash Deposits locally. However, the discrepancy of apparent vertical offset between the San Pedro Formation and base of the older Benedict Canyon Wash Deposits (20 feet compared to 31 feet respectively) may very well be an indication of lateral slip across this fault. Based on these data, Fault E1 is not active.

12.1.6 Fault E2

Fault E2 was identified along Transects T1-8, T2, and T3 (Plates KGS-T1, -T2, and –T3). Plate ES-2b shows the surface projection and northwestward dip of Fault E2. The fault offsets the top of the San Pedro Formation approximately 12 feet in an apparent reverse displacement. The base of the older Benedict Canyon Wash Deposits is displaced approximately 22 feet by apparent reverse displacement which is greater than that observed by the San Pedro Formation either due to strike-slip motion or difficulties in the ability to identify the base of the older Benedict Canyon Wash Deposits. However, Fault E2 offsets basal members of the older Benedict Canyon Wash Deposits approximately 10 to 15 feet vertically and likely was active during deposition of the Benedict Canyon Wash Deposits and Cheviot Hills Deposits. This is supported by the observation that the older Benedict Canyon Wash Deposits thickens and the Cheviot Hills Deposits thins within the E1 and E2 fault zone. Based on these transect data, it is possible that a depression/channel was created during Cheviot Hills Deposits deposition, then a soil pedon associated with soil marker horizon B was able to form at the surface within the depression at the top of the Cheviot Hills Deposits. This surface was subsequently faulted and overlain by the older Benedict Canyon Wash Deposits. Thus, as will be discussed for Faults F, F1 and F2 in the next section, Fault E2 assisted in the creation of the depression that deformed the 315T-300T fan-terrace approximately 150,000 to 200,000 years to allow the ancient Benedict Canyon Wash to flow through the Cheviot Hills (Figure 10, Plate ES-16).

Parsons (2011) shows Fault E2 extending nearly to the surface. Based on Plates KGS-T1, Fault E2 may extend to within 11 to 12 feet of the ancient surface (measured from the base of the artificial fill), which represents older Benedict Canyon Wash Deposits that are a minimum of 40,000 years old. On Transect T2 (Plate KGS-T2), Fault E2 is shown to split (similar to Parsons, 2011), but the fault does not offset a fining upward sequence basal erosion surface at depths of 34 to 38 feet deep as measured from the base of the artificial fill. Based on this interpretation, Fault E2 is not active.

12.1.7 Faults F, F1 and F2

Faults F, F1 and F2 are a zone of faulting identified by both Parsons (2011) along Transect T3 and T1-8 and by MACTEC (2010). This is shown on Plate ES-10. As discussed earlier, Fault F may split near Transect T1-8 into possibly two faults that are observed on Transect T7 (Plates ES-2b, KGS-T1, and KGS-T7). On Parsons (2011) Transect T3, Fault F consists of possibly 4 splays that all dip toward the north and exhibit apparent normal dip-slip displacement (Figure 10 and Plate ES-2b). All the faults within the Fault “F” zone dip north with apparent normal dip-slip separation. Fault F on Transect T1-8 (Plate KGS-T1) offsets San Pedro Formation approximately 55 feet. Although it is difficult to identify the base of the Cheviot Hills Deposits near Fault F on Transect T1-8, it is shown on Plate KGS-T1 to be offset approximately 38 feet. It is not clear if Fault F in Transect T1-8 offsets the base of the older Benedict Canyon Wash Deposits. There is a fairly well developed basal erosion surface identified as the possible base of the Benedict Canyon Wash Deposits that has likely not been offset more than 5 feet if it is indeed faulted. Fault F in Transect T1-8 may extend to within 18 feet of the ancient surface (measured from the base of the artificial fill) where it likely does not offset a basal erosion surface within the older Benedict Canyon Wash Deposits. This observation would indicate that Fault F is not active.

Toward the northeast, Fault F splits into two faults (Faults F1 and F2) or possibly more that extend all the way to Transect T7 (Plates ES-2b and KGS-T7). Although Fault F1 on Transect T7 is not shown to actually offset any units, sufficient difficulties in correlating units at depths deeper than approximately 115 feet suggest that faulting may occur within San Pedro Sequence and basal units Cheviot Hills Deposits. Alternatively, and as shown on Plate KGS-T7, erosion at the base of the Cheviot Hills Deposits, and/or an increase in dip angle (folding) of the San Pedro Sequence and basal Cheviot Hills Deposits may have contributed to the local discrepancies. In either case, if Fault F1 exists, it appears to not offset numerous soil marker horizons (A, B, C, and D) indicating that this fault is not active.

Fault F2 occurs south of Fault F1 (Plate ES-2b) in Transect T7 (Plate KGS-T7) and offsets SPS and the entire section of Cheviot Hills Deposits. If Fault 2 offsets the base of the older Benedict Canyon Wash Deposits vertically, then the apparent dip-slip separation is likely less than 5 feet. It appears evident that soil marker horizon A estimated to be 134,000 years old is not offset by Fault F2 thus indicating that the fault is not active. It is worth noting that Fault F2 displaces the Cheviot Hills Deposits - San Pedro Formation contact approximately 25 feet in apparent normal dip-slip separation, which is approximately half of that observed along Transect T1-8 (~55 feet). This observation in addition to the fault zone splaying out toward the northeast, suggest that the fault zone is dying out toward the northeast.

Normal displacement across the “Fault F” zone resulted in the development of a local depression (half-graben) that disrupted the 315T-300T fan-terraces. The depression allowed for the capture of the ancient

Benedict Canyon Wash to flow south through the Cheviot Hills beginning approximately 150,000 to 200,000 years ago. The older Benedict Canyon Wash Deposits filled this ancient channel system.

12.2 Geomorphology regarding potential fault activity

Two late Pleistocene fan-terraces occur in Century City that assist in the evaluation of fault activity. These include the ~40,000 year old 275T fan-terrace of the older Benedict Canyon Wash Deposits and the 150,000 to 200,000 years old "300T" fan-terraces of the Cheviot Hills Deposits (Figure 10; Plate ES-4). The fan-terrace surfaces are sufficiently old to have experienced a minimum of four major earthquakes assuming that local faults have a recurrence level equal to at least 11,000 years, the definition of an active fault in the State of California (Bryant and Hart, 2007). Fault scarps should be present if these faults are active.

As discussed earlier in this report, normal offsets across Faults E2, F, F1 and F2 of the Santa Monica Boulevard Fault Zone created a local depression in which the ancient Benedict Canyon Wash flowed south through the Cheviot Hills and filled with older Benedict Canyon Wash Deposits between 40,000 to 200,000 years ago. No visible scarps are observed on the 5-foot contour lines shown on the Hoots (1931) topographic map (base map for Figure 10) associated with Faults F, F1 and F2. In addition, the southwest end of Fault F, which contains several fault splays, occurs across a 275-285T fan-terrace (Plate ES-4) that appears to not be deformed (Figure 10). Accordingly, based on these geomorphic data, Faults F, F1 and F2 are not active.

A small swale between faults C and E2 occurs on the northern edge of the 275T surface near the toe of the southwestern end of the 30-35 foot high escarpment. The swale was likely produced by fluvial erosion parallel to the trend of the escarpment on the 275T fan-terrace and not faulting.

As discussed earlier in this report, vertical reverse displacements across Faults A, B, C and E1 likely assisted in producing the 30-35 foot high escarpment on the north side of the 275T fan-terrace (Figure 10). However, the escarpment evolved from both faulting and fluvial processes. Northward lateral migration of the ancient Benedict Canyon Wash during deposition of the older Benedict Canyon Wash Deposits occurred in addition to infilling of the ancient Benedict Canyon Wash channel system. Faulting continued during deposition of the older Benedict Canyon Wash Deposits by may have ceased prior to 40,000 to 50,000 years ago. Therefore, the escarpment may have exhibited higher relief in the past as the ancient Benedict Canyon Wash channel system filled with sediments. Additionally, the escarpment may have been located tens of feet further to the southeast prior to northward lateral migration and associated erosion of the ancient Benedict Canyon Wash. It is therefore difficult to determine fault activity based on the geomorphology of the 30-35 foot high escarpment associated with Faults A, B, C and E1 but possible that it is a relict (in-active and degrading) fault scarp.

Faults C and E occur within a topographic swale southwest of the location of Faults D1 and D2 (Figure 10) that represents the northeast end of the topographic Santa Monica Boulevard Lineament (SMBL; Plate ES-4). The railroad already exists on the Hoots (1931) topographic map indicating that some cut and fill grading had occurred along the Santa Monica Boulevard Lineament accentuating the lineament; however, the railroad line likely followed an existing topographic swale in the region suggesting that the Santa Monica Boulevard Lineament is natural. The topographic lineament is primarily associated with Cheviot Hills Deposits; however, based on evaluation of geologic unit types in the transect subsurface data (Transect 3) and their respective elevations, older Benedict Canyon Wash Deposits may be deposited within the swale containing Faults C and E. Accordingly, it is difficult to determine the relative timing of local faulting, erosion, and deposition within the Santa Monica Boulevard Lineament in this region and therefore, difficult to evaluate activity of Fault C and E based on these geomorphic and geologic data.

13 LATE QUARTERNARY DEFORMATION AND DEPOSITIONAL HISTORY IN CENTURY CITY (CHEVIOT HILLS)

The San Pedro Formation was deposited in a marine environment of approximately 600,000 years; however, it may have been on the order of a million years ago in the Cheviot Hills area. As the sea retreated, terrestrial sediments were deposited conformably upon the San Pedro Formation prior to 500,000 years ago. These terrestrial deposits include units E, F, Qfob, and Qeb as shown on Figure 3 (Plate ES-3). Collectively, the San Pedro Formation, and units E, F, Qfob, and Qeb are conformable and hence, deposited during a period of time when tectonic deformation did not occur or was minor in the Cheviot Hills region. These units are referred to as the San Pedro Sequence (SPS; Figure 3).

Erosion and uplift (folding) occurred after deposition of the San Pedro Sequence and prior to deposition of Cheviot Hills Deposits developing a gentle angular unconformity between these units. Uplift and folding continued during deposition of Cheviot Hills Deposits; however, the Cheviot Hills likely did not exist as a topographic feature approximately 150,000 to 200,000 years ago at the end of deposition of the Cheviot Hills Deposits. Geomorphically the region was probably similar to fan surfaces east of the Cheviot Hills and WBHL (Plate ES-4). The WBHL either did not exist, or was quite subdued geomorphically during this time. The “300T” fan-terraces, about 150,000 to 200,000 years old, throughout the Cheviot Hills are remnants of this paleo-landscape (Plate ES-4). Subsequent uplift however associated with local folding (Plate ES-4) elevated the eastern Cheviot Hills and allowed the Benedict Canyon Wash to incise and produce the geomorphic West Beverly Hills Lineament and south flowing ancient Benedict Canyon Wash through the Cheviot Hills. The uplift may still continue which assisted in the abandonment of the ancient Benedict Canyon wash 40,000 years ago (275T surface, Figure 10). Incision of the Benedict Canyon Wash along the trace of the West Beverly Hills Lineament produced several antecedent streams that are labeled with a red A on Plate ES-4. In addition, the south flowing ancient Benedict Canyon Wash through the Cheviot Hills in the area of the older Benedict Canyon Wash Deposits is also considered an antecedent stream.

The upper plate Santa Monica Boulevard Fault Zone deformed the 300T surfaces, suggesting that activity on this fault zone started approximately 150,000 to 200,000 years ago (Plate ES-16). The net displacement of the Santa Monica Boulevard Fault Zone produced extension across Faults E2, F, F1 and F2 and compression across Faults A, B, C and E1 produced by right-lateral motion across the Santa Monica Boulevard Fault Zone in Century City. The combined displacements produced a local depression within the Cheviot Hills that captured or split the Benedict Canyon Wash southwestward through the Cheviot Hills (Plate ES-1b) and along the West Beverly Hills Lineament east of Beverly Hills High School.

The older Benedict Canyon Wash Deposits filled the structurally and erosionally produced ancient channel between ~40,000 to 150,000 years ago (Plate ES-1b). Control stemmed from faulting along the Santa Monica Boulevard Fault Zone, local anticlinal formation, and regionally lowered base levels corresponding to MIS 6, about 150,000 years ago. The southwest channel through Century City was abandoned ~40,000 years ago producing the 275T fan-terrace (Plate ES-4) near the proposed Santa Monica subway station.

A diagrammatic north-south cross-section through the Cheviot Hills shows an inferred blind Santa Monica Fault Zone extending beneath the Cheviot Hills (Plate ES-16). Ostensibly, this fault zone has left-lateral and reverse components of slip (oblique fault). However, the north, upper-plate sediments are deformed by folding and secondary steeply dipping faults of the Santa Monica Boulevard Fault Zone. The extensional (normal) component of the Santa Monica Boulevard Fault Zone may stem from a releasing bend orientation of the Santa Monica Boulevard Fault Zone relative to the Santa Monica Fault Zone from the west (Plate ES-17). The older Benedict Canyon Wash Deposits were deposited in the depression within the uplifted Cheviot Hills nestled between 300T fan-terraces (Plate ES-16).

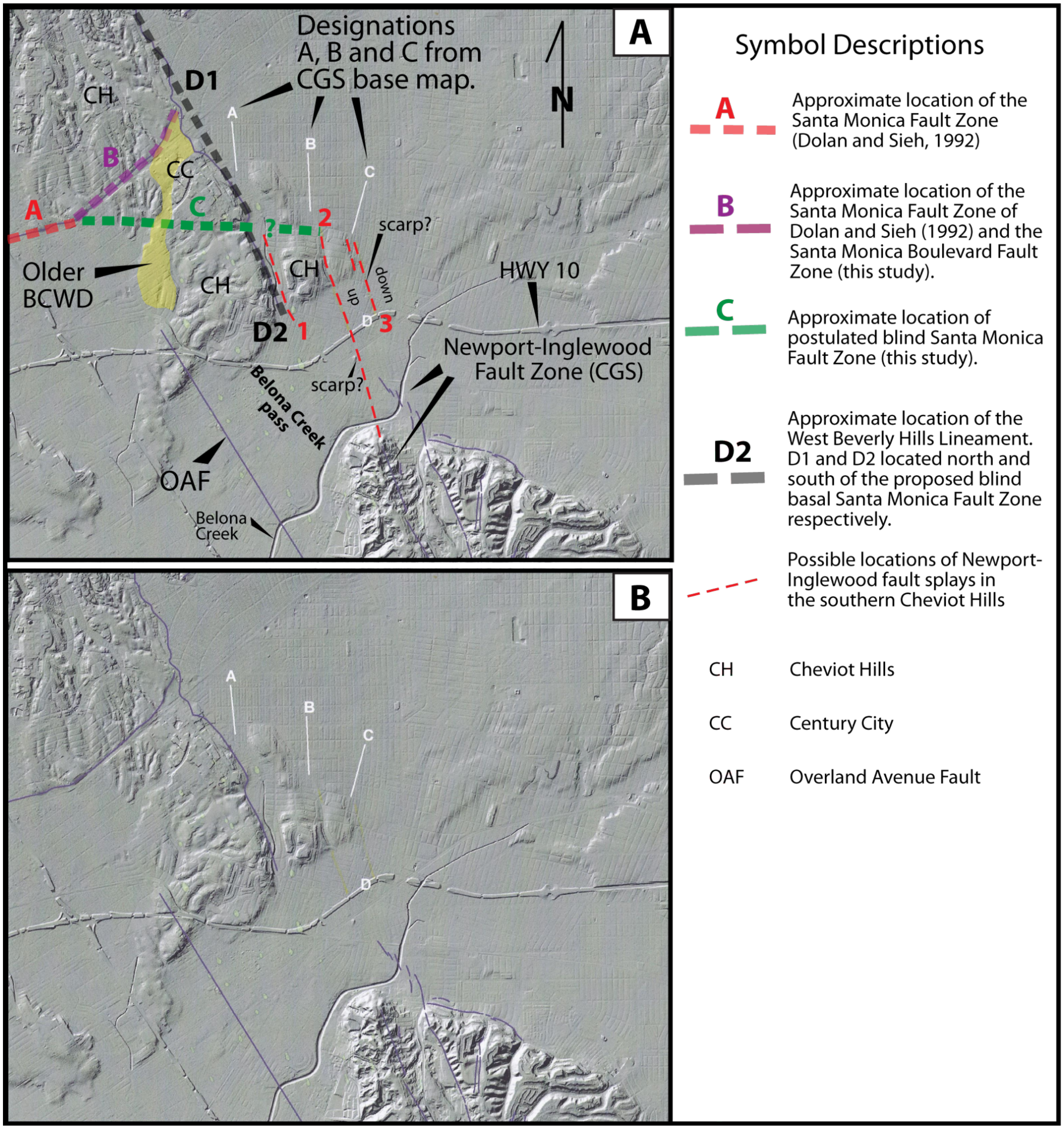
14.0 THE NEWPORT-INGLEWOOD FAULT ZONE IN THE CHEVIOT HILLS

A LiDAR image provided by the California Geological Survey (CGS, personal communication, 2012) of the Cheviot Hills and surrounding areas is provided on Figure 12. For reference, fault segments A, B, and C, the West Beverly Hills Lineament, and approximate limits of the older Benedict Canyon Wash Deposits from Figure 3 are shown on diagram A of Figure 12. Diagram B shows an unaltered version of the CGS LiDAR data showing the Overland Avenue Fault (OAF), traces of the Newport-Inglewood Fault Zone, and the eastern edge of the escarpment associated with the West Beverly Hills Lineament. In addition, CGS shows the potential northward termination of faults A, B and C (white), speculating that strands of the Newport-Inglewood Fault Zone may extend along the West Beverly Hills Lineament or within two topographic depressions east of the West Beverly Hills Lineament in the southeastern most Cheviot Hills. The red-dashed lines labeled 1, 2 and 3 (red) are Kenney GeoScience speculative locations for strands of the Newport-Inglewood Fault Zone between the Baldwin Hills and the southeastern Cheviot Hills.

The LiDAR data shows a subtle topographic rise of the planar alluvial surface across Fault 3 (red) south of the southeastern Cheviot Hills suggesting a fault scarp. Fault 3 (red) aligns with northwest trending faults in the eastern portion of the Newport-Inglewood Fault Zone in the Baldwin Hills. Along Fault 2 (red), a small topographic hill bounded by planar alluvial surfaces is on strike with a valley in the southeastern Cheviot Hills and CGS mapped locations for faults in the western portion of the Newport-Inglewood Fault Zone in the Baldwin Hills. Fault 1 (red) on Figure 12 is shown within an antecedent drainage associated with Benedict Canyon Wash through the southern Cheviot Hills. This fault does not align with mapped faults in the Baldwin Hills, however a left step-over in the NIFZ cannot be ruled out.

These data suggest the Newport-Inglewood Fault Zone occurs in the southeastern Cheviot Hills, and that most geomorphic evidence of faulting between the northern Baldwin Hills and the southeastern Cheviot Hills was eroded or buried by fluvial process associated with Belona Creek. This region is referred herein as the Belona Creek pass (Figure 12). Currently, Belona Creek is at the south side of Belona Creek pass and possibly migrated toward the south during the late Quaternary. If true, then alluvial sediments in the northern portion of Belona Creek pass would be older than the sediments on the south side. Accordingly, sediment north of Highway 10 within Belona Creek pass may be sufficiently old to exhibit fault scarps similar to that observed across Fault 3 (red, Figure 12).

Figure 12: Modified (diagram A) and unmodified (diagram B) LiDAR image provided to Kenney GeoScience by the California Geological Survey (2012).



15.0 CONCEPTUAL TECTONIC MODEL FOR THE CHEVIOT HILLS AND SURROUNDING REGION

Plate ES-18 portrays a late Quaternary kinematic model for the Santa Monica Fault Zone (SMFZ), Newport-Inglewood Fault Zone (NIFZ), and Hollywood Fault Zone (HFZ). The model assumes that the Santa Monica Boulevard Fault Zone (SMBFZ) is an upper-plate "secondary" fault system to the Santa Monica Fault Zone. The major premise here is that the Newport-Inglewood Fault Zone does not cut the Santa Monica Fault Zone, but instead, extends beneath it. Eastward, the Santa Monica Fault Zone may connect with other late Quaternary faults such as the Wilshire Boulevard Fault Zone of Hummon et al., (1994). Motion across the Newport-Inglewood Fault Zone pushes the Santa Monica Block and deforms the Santa Monica Fault Zone, resulting in uplift west of the Newport-Inglewood Fault Zone and relative depression the east. This geometry gave rise to late Quaternary folding and uplift parallel to and in the location of the West Beverly Hills Lineament (WBHL). This model does not require the Newport-Inglewood Fault Zone to extend to the surface along the West Beverly Hills Lineament; however, motion across the Newport-Inglewood Fault Zone produced the east-facing West Beverly Hills Lineament escarpment.

The model also postulates that folding causes most deformation of the Cheviot Hills. Tsutsumi et al., (2011) and Wright (1991) proposed that much of the late Quaternary deformation associated with motion across the northern Newport-Inglewood Fault Zone is attributed to folding at depth. This model extends the Hollywood Fault Zone to west of the West Beverly Hills Lineament, suggesting that the Newport-Inglewood Fault Zone may also extend under the Hollywood Fault Zone. If this is true, then slip transfer between the Santa Monica Fault Zone and the Hollywood Fault Zone would occur throughout the Cheviot Hills at a minimum and not simply across the north trending region of the West Beverly Hills Lineament.

If the Santa Monica Fault Zone does connect with the Wilshire Boulevard Fault Zone east of the West Beverly Hills Lineament (Newport-Inglewood Fault Zone), then it suggests that lateral slip on this system may vary from left-lateral west of the West Beverly Hills Lineament and right-lateral to the east of the West Beverly Hills Lineament. The Cheviot Hills would exist near the transition of these two slip terrains.

16.0 EVALUATION OF FAULT SOURCE PARAMETERS FOR THE SANTA MONICA FAULT ZONE

Moment magnitude (Mo) values were determined based on reasonable fault lengths and presuming that the Santa Monica Fault Zone (SMFZ) is an oblique strike-slip reverse fault zone. In addition, estimated slip-per-event values were determined for the Santa Monica Fault Zone. These issues are discussed below.

16.1 Estimated Seismic Moment (Mo) and Moment Magnitude (Mw)

Kanamori and Anderson (1975) equation was used to determine the potential seismic moment magnitude for a major (>6.0) earthquake on the Santa Monica Fault Zone.

Mo = uAD

u = rigidity constant- Shear Modulus ($3.0x10^{11}$ dyne/cm^2 from DePolo and Slemmons (1990). Values of u range from $3.0x10^{11}$ dyne/cm^2 to $3.5x10^{11}$ dyne/cm^2 for southern California. The 3.0 value is the same used by Wells and Coppersmith (1994).

A = area of seismogenic fault plane in units of cm.
The area was calculated by assuming that the seismogenic portion of the fault was on a 30 degree dipping plane from a depth of 2 to 14 km (~1.2 to 8.7 miles).

D = Average Displacement on the fault in cm.

Moment magnitude (Mw) was calculated utilizing the equation:

Mw = 2/3Log(Mo) – 10.7 Hanks and Kanamori (1979).

16.2 Santa Monica Fault Parameters

Fault Length:

Based on published reports and fault maps, the length of the terrestrial Santa Monica Fault Zone is ~12 km (7.5 miles) and offshore faults running parallel to the Malibu Coast fault in the Pacific Ocean is 24 km (15 miles). This equals a total mapped length (Jennings, 1994) of 36 km (22.4 miles). However, fault rupture is known to extend at depth without surface rupture, which indicates that the published fault length for the Santa Monica Fault of 40km is reasonable (Dolan et al., 2000). The 40 km depth was utilized in the provided calculations.

Fault Rupture Area:

The Santa Monica Fault Zone rupture area (length times down-dip width) was calculated based on a fault plane dipping 30 degrees. The Santa Monica fault has a complex history extending back to normal displacement during the Miocene that subsequently was reactivated (Wright, 1991). Boring data evaluation by Wright (1991) and near surface seismic profiling (Catchings, et al., 2008; Dolan and Pratt, 1997; Pratt et al., 1998) indicate that the fault dips to the north, and that the near surface dip may be as low as 20 degrees. However, the true dip extending to the brittle ductile shear zone (~14km; 8.7 miles) is not fully known. Fault motion since the latest Quaternary is considered to be oblique left-lateral reverse. For the calculation of fault area, a dip of 30 degrees was utilized on a plane extending from a depth of 2 to 14 km (1.2 to 8.7 miles).

Average Displacement:

Kanamori and Anderson (1975) indicate that the average displacement value should be used to calculate seismic moment. During fault rupture, displacement is obviously zero at the ends of the rupturing fault, with a maximum somewhere along the length of the rupturing fault. In theory, the average displacement value is simply the average displacement occurring across the entire rupturing fault plane. The average displacement values were determined from Wells and Coppersmith (1994) that provided source parameters for reverse, lateral (strike-slip) and normal faults. However, Wells and Coppersmith (1994) does not provide data for oblique faults although oblique earthquake event data was utilized in their regressions. Regardless, regression curves for all of these fault types comparing surface rupture length and average displacement all intersect near the surface rupture length of 40 km (~25 miles). This provides an average displacement value of D = ~1.85 meters (~6 feet).

16.3 Estimated Mw values for the Santa Monica Fault Zone

Mw estimates for a fault length of 40 km (~25 miles; A = 9.6×10^{12} cm^2).

Mw = ~7.1 with average displacement D = 185 cm (most probable) [1.85 meters] = ~6 feet

Mw = ~6.9 with average displacement D = 100 cm [1 meter] = ~3.3 feet

Mw = ~7.3 with *maximum* displacement D = 300 cm (least probable) [3.0 meters] = ~9.8 feet

Mw estimates for a fault length of 12 km (A = 2.88×10^{12} cm^2)

Mw = ~6.4 with average displacement of D = 55 cm [0.55 meter] = ~1.8 feet

Anderson, et al. (1996) proposed a correlation between slip rate and earthquake magnitude. Ostensibly therefore, the largest earthquakes will occur on the slowest slipping faults if the rupture length is held constant. This suggests that slip rate is an important parameter to estimate earthquake magnitude. Essentially, their results suggest that a pure moment magnitude calculation as provided above may underestimate Mw values for faults exhibiting relatively slow slip rates as is currently understood for the Santa Monica Fault Zone.

Based on the calculated values, average displacement across the Santa Monica Fault Zone will be approximately 1.8 meters (~6 feet). This slip would be partitioned across numerous faults and be absorbed by folding within the Cheviot Hills.

17.0 DISCUSSION

The major northwest-southeast striking faults associated with the West Beverly Hills Lineament - Newport-Inglewood Fault Zone proposed by Parsons (2011) do not exist in the near surface associated with the West Beverly Hills Lineament at least in the areas where subsurface data has been recently collected. However, it cannot be ruled out that northwest striking strike-slip faults associated with the Newport-Inglewood Fault Zone may occur further east. At least one fault and possibly others identified by Parsons (2011) associated with the West Beverly Hills Lineament likely do exist (Faults F1 and F2), but are considered herein to be part of the Santa Monica Boulevard Fault Zone, which strike northeast (Plate ES-2b). The West Beverly Hills Lineament is a geomorphic lineament along the eastern side of the Cheviot Hills (Plate ES-1b), but it is proposed that the lineament developed due to folding and associated uplift of the Cheviot Hills, and concurrent erosion by Benedict Canyon Wash (Plate ES-18).

Kenney GeoScience agrees with many of the fault locations proposed by Parsons (2011) along the Santa Monica Boulevard Fault Zone (compare Plates ES-2a and ES-2b). The local geomorphology of the region provides some insights regarding the activity and style of local faulting. Geomorphology suggests that the Santa Monica Boulevard Fault Zone has likely not experienced repeated reverse rupturing events, and instead has likely experienced primarily oblique right-lateral strike-slip normal displacement (Plates ES-4, ES-5 and ES-6) with localized areas of reverse faulting due to fault orientations (local restraining bend). Accordingly, that the Santa Monica Boulevard Fault Zone may be a secondary upper plate fault zone to the primary basal reverse fault for the Santa Monica Fault Zone, which implies that it has not yet been identified but would occur in the southern Cheviot Hills.

Additional evidence supporting the conclusion that the Santa Monica Boulevard Fault Zone is an upper plate secondary fault to the primary Santa Monica Fault Zone includes:

- The relatively straight trend of the geomorphic lineament along Santa Monica Boulevard, which is more common for strike-slip than for dip-slip faults (Plate ES-4)
- Right-laterally deflected drainages across the Santa Monica Boulevard Fault Zone (Plates ES-7b and ES-7c)
- The style of apparent dip-slip separations across various faults along the Santa Monica Boulevard Fault Zone observed on the transects cross sections (Plates KGS-T1, T2, T4, T7, and Plate ES-2b)
- Local uplift across faults A, B, C, and E1 are consistent with right-lateral displacement across the Santa Monica Boulevard Fault Zone inferring a local restraining bend orientation (Figure 10).
- Development of the local geomorphic depression across Faults E2, F and F2 is consistent with right-lateral displacement across the Santa Monica Boulevard Fault Zone (Figure 10 and Plate ES-2b).
- The general trend of the Santa Monica Boulevard Fault Zone is on average approximately 24 to 35-degrees more northerly than the general trend of the Santa Monica Fault Zone from the west, consistent with documented historical surface rupture of secondary upper plate structures associated with oblique left-lateral reverse faults (23 to 42 degrees; Plates ES-11 and ES-12).
- The dip of the Santa Monica Fault Zone at the West Los Angeles Veterans Administration Hospital site is likely in the range of 20 to 30 degrees just 1 to 2 miles west of Century City. However, the general dip of the Santa Monica Boulevard Fault Zone is 50 to 80 degrees, consistent with secondary upper plate faults.

These data suggest that the primary basal reverse fault for the Santa Monica Fault Zone has likely not been identified in the Cheviot Hills, which adversely affects our ability to evaluate seismic hazards in the region until the location and style of deformation of the Santa Monica Fault Zone is fully understood in the Cheviot Hills. However, there are other issues that greatly affect the evaluation of local seismic hazards, and these include whether or not the Santa Monica Boulevard Fault Zone is active, and the evaluation of local folding.

A number of lines of evidence suggest the Santa Monica Boulevard Fault Zone is not active. This is provided by the relatively undeformed approximately 40,000 years old 275T fan-terrace surface of older Benedict Canyon Wash Deposits (Figure 10), and the identification of some possible undisturbed erosion surfaces and associated overlying fining upward sequences across the Santa Monica Boulevard Fault Zone in the near surface (Plates KGS-T1, T2, and T7).

Evaluation of Parsons (2011) transects data shown on Plates KGS-T1, T2, and T7 indicate the possibility that all of the faults associated with the Santa Monica Boulevard Fault Zone are not active. Although not conclusive, most of the faults appear to be overlain by undeformed erosion surfaces and sediments associated with the older Benedict Canyon Wash Deposits. It is recommended that addition subsurface fault studies be conducted across strands of the Santa Monica Boulevard Fault Zone utilizing fault trenching if feasible in regions where the older Benedict Canyon Wash Deposits are exposed. This approach will provide essentially the youngest sedimentary units available that would presumably overlie the faults. A good place for the investigation would near the intersection of Parsons (2011) Transects 1 and 2.

Transect 3 of Parsons (2011) shows faults associated with the Santa Monica Boulevard Fault Zone quite close to the surface and thus suggesting that they may be active. However, it is also possible that the land surface has simply eroded downward and into older faults, or that these faults did rupture to the surface within the Cheviot Hill Deposits. In either case, faults identified in Transect 3 could be inactive but still reach the surface, and determining fault activity in the exposed Cheviot Hill Deposits in the region would likely prove problematical.

It is clear that folding is a key deformational process if not the primary mode of deformation within the Cheviot Hills. San Pedro Sequence is more folded than the overlying Cheviot Hills deposits, suggesting that the folding may have begun around 600,000 years ago. Folding continued during and after deposition of the Cheviot Hills Deposits demonstrated by folding of the 150,000 to 200,000 years old fan-terraces throughout the Cheviot Hills ("300T" surfaces). Older Benedict Canyon Wash Deposits appear to be folded at depth, but it is unclear if the upper members are. An uplift rate of the anticline based on ~12.2 meters (~40 feet) of uplift during the past 600,000 years (minimum estimated age of the top of the San Pedro Formation; ECI, 2012) is approximately 0.02 mm/year (~0.0008 inches/year = 0.8 inches/thousand years). Based on all the data, it is likely that folding continues today, and thus should be considered active.

18.0 CONCLUSIONS

The preliminary conclusions of this study are:

- A late Quaternary geologic history of the Cheviot Hills greatly assists understanding of the timing and scale of local deformational structures and sedimentary units.

- A detailed geomorphic analysis of the Cheviot Hills improves our understanding of the style, age, and location of faults.

- The Parsons (2011) proposed West Beverly Hills Lineament-Newport-Inglewood Fault Zone (WBHL-NIFZ) do not exist the study area.

- At least one and possibly several West Beverly Hills Lineament-Newport-Inglewood Fault Zone faults shown by Parsons (2011) exist. These however, are part of the northeast trending Santa Monica Boulevard Fault Zone (Faults F1 and F2 on Plate ES-1a), trending nearly 90-degrees to the West Beverly Hills Lineament-Newport-Inglewood Fault Zone. Fault F2 (Plate ES-2b) crosses Parsons (2011) Transect 7 immediately south of Transect 4 intersection and likely connects with the southern mapped fault by Parsons (2011) with the Santa Monica Boulevard Fault Zone along Transects 3 and 1-8. Fault F2 is in close proximity to the southern most identified in the MACTEC (2010) geophysical survey report (2010) and appears to enter the northern limits of Beverly Hills High School (Plate ES-10).

- Santa Monica Boulevard Fault Zone faults identified in this study are consistent with faults identified by Parsons (2011) with some exceptions as discussed above.

- The Santa Monica Boulevard Fault Zone splays outwards towards the east in the study area, suggesting that numerous relatively smaller scale faults may occur between Faults A through F that would prove difficult to identify based on the resolution of the existing data (Plate ES-1a).

- The Santa Monica Boulevard Fault Zone is a secondary upper plate fault zone associated with the basal oblique left-lateral reverse Santa Monica Fault Zone. This conclusion infers that the Santa Monica Fault Zone has not been identified in the Cheviot Hills and if it does exist would likely occur in the southern Cheviot Hills (Plates ES-4, ES-5, ES-7b, ES-16, and ES-18).

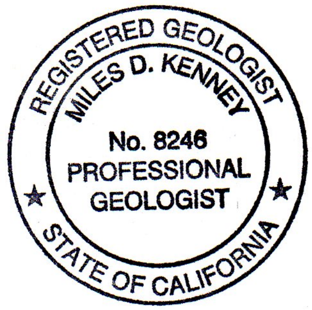
- The Santa Monica Boulevard Fault Zone may be inactive. Activity on various individual faults within the fault zone likely ceased at different times. The Santa Monica Boulevard Fault Zone was active approximately 150,000 years ago, numerous strands within this fault zone offset a soil profile dated at approximately 134,000 years old, but may have ceased prior to approximately 40,000 to 50,000 years ago. However, a more detailed subsurface fault investigated is warranted to test this hypothesis.

- Geophysical seismic reflection data provided in the Parsons (2011) report infers that some relatively deep and likely inactive faults occur south of the identified Santa Monica Boulevard Fault Zone (Plate ES-2b). These faults are poorly understood but may provide some insights on the tectonic and structural evolution of the region in addition to potential seismic hazards. For example, have faults similar to the Santa Monica Boulevard Fault Zone migrated north over time (time transgressive) suggesting a possible bend in the underlying primary basal reverse Santa Monica Fault (Plates ES-16)? Could these faults be blind producing near surface folding?

- The Newport-Inglewood Fault Zone likely exists in the southeastern Cheviot Hills (Figure 12) east of the West Beverly Hills Lineament. However, the northern termination of this fault zone is unknown but could extend northward, east of the study area.

- A conceptual kinematic model is proposed for the creation of the West Beverly Hills Lineament - Newport-Inglewood Fault Zone. The model proposes that the Newport-Inglewood Fault Zone extends under the eastern Cheviot Hills and beneath the Santa Monica Fault Zone (Plate ES-18). As the Santa Monica tectonic block moves north it deforms the basal Santa Monica Fault Zone and causes uplift in the Cheviot Hills in a region parallel to the Newport-Inglewood Fault Zone and West Beverly Hills Lineament. The uplift in the form of folding the Cheviot Hills strikes parallel to the West Beverly Hills Lineament. As the uplift continued, erosion occurred along the strike of the uplift thus creating the east facing, northwest-southeast striking escarpment referred to as the West Beverly Hills Lineament. This model allows for the NIFZ to be the causative agent for the development of the West Beverly Hills Lineament, but does not require faults associated with the Newport-Inglewood Fault Zone to reach the surface.

- The results of this study strongly indicate a sufficient lack of understanding of the location, age, and style of deformation in the Cheviot Hills to adequately evaluate seismic hazards both in terms of ground shaking, faulting and folding (tilting). Results from this study should assist however in conducting future investigations.



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Kenney GeoScience

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APPENDIX A – ATTACHED REPORTS

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; ECI Project No. 3205.02; *report in*: Leighton Consulting Inc. (LCI), 2012; Fault hazard assessment of the West Beverly Hills Lineament, Beverly Hills High School, 241 South Moreno Drive, Beverly Hills, California; report prepared for Beverly Hills Unified School District; report dated April 22, 2012, LCI Job Project No. 603314-002.

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

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	Consistency 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 3/2	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	
7BClam2	350 - 371	21	SCL & C	10YR 3/3 & 7.5YR 3/4		sg & 2cabk		vfr	s	p	3npf&po, 3mkbr	Moist when sampled and described
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

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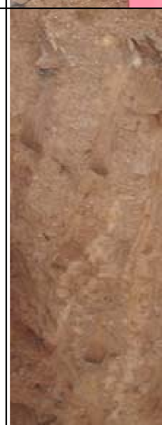
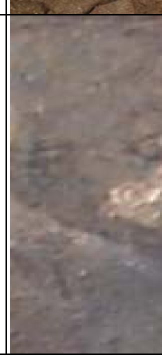
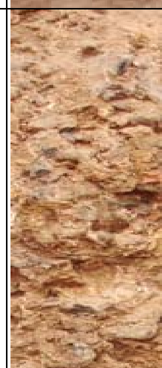
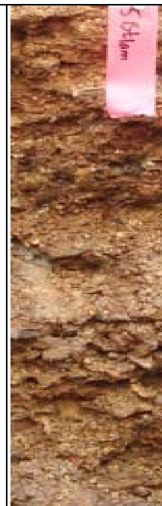
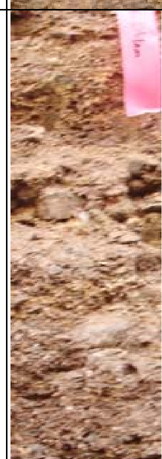
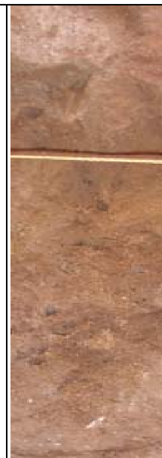
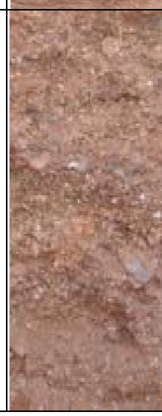
APPENDIX A:
Beverly Hills High School Trenching Project
SOIL PROFILE DESCRIPTIONS

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.

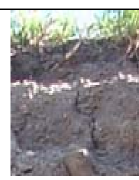
Depth (ft)	Depth (cm)	Horizon Designation	Photo	Description
0 – 0.36	0 – 11	Ap (Afu)		Gravelly clayey sand with scattered nails and pieces of wire. No samples collected. Abrupt smooth boundary.
0.36 – 1.15	11 - 35	Ej		CLAY LOAM; dark yellowish brown (10YR 4/4) with many distinct fine reddish brown, yellowish 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.

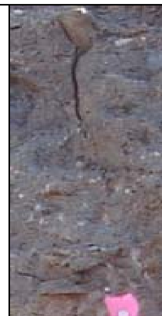
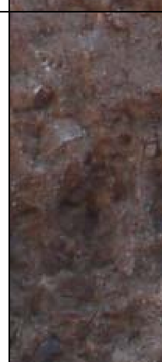
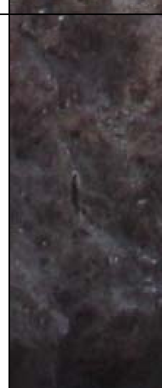
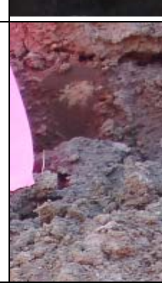
4.76 – 6.59	145 – 201	2Bt3/E		Argillic horizon with albic tongues. Argillic section: SANDY CLAY; dark brown (7.5YR 5/4) with few dark reddish brown (5YR 3/3) mottles when dry, dark brown (7.5YR 3/3) when moist; strong coarse angular blocky structure; slightly hard when dry, friable when moist, sticky 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).

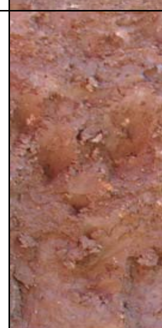
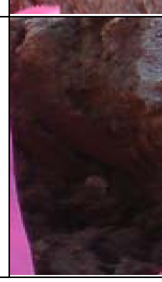
8.73 – 10.01	266 – 305	$5BC_{lam}2$		Fine to coarse SANDY GRAVEL with SANDY CLAY LOAM Bt lamellae; clay is dark brown (7.5YR 3/4) when dry, brown (7.5YR 4/4) when moist; single-grained, weak to moderate medium subangular blocky structure where Bt_{lams} are present; sandy gravel is loose when dry and 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.

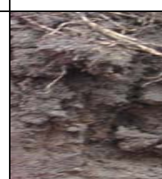
0.33 – 1.64	10 - 50	Ap2		CLAY LOAM with gravel and cobbles; dark grayish brown (10YR 4/2) when dry, very dark brown (10YR 2/2) when moist; strong coarse angular blocky structure; very hard when dry, very firm when moist, sticky and plastic when wet; many thin clay films on ped faces; abundant roots throughout, 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

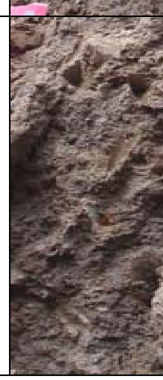
				wavy boundary.
5.08 – 5.87	155 - 179	3BCb1		Very fine SANDY CLAY to CLAY; brown (10YR 4/3) when dry and mixed, dark brown (7.5YR 3/2) when moist; weak fine to medium subangular blocky structure; very friable when moist, very sticky and plastic to very plastic when wet; many pinhole pores; common roots; 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.

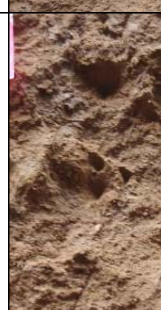
9.97 – 10.79	304 – 329	7Btb2		Gravelly SANDY CLAY; brown and dark brown (7.5YR 4/4 and 3/3) when moist, with dark brown (7.5YR 3/2) clay films; moderate medium to coarse angular blocky structure; friable when moist, very sticky and plastic when wet; many moderately thick clay films bridging grains and 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

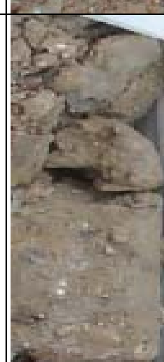
				fine pinhole pores; few rounded to subrounded gravel; abrupt to clear and wavy boundary.
2.13 – 2.89	65 – 88	2Ab1/2Bt1b		CLAY; very dark grayish brown (10YR 3/2) when dry, very dark brown (10YR 2/2) when moist; moderate medium angular blocky breaking to moderate fine angular blocky structure; very hard 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.

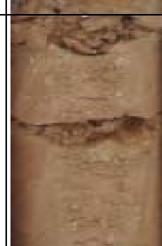
6.33 – 7.55	193 – 230	4Btb4		CLAY; very dark gray and dark brown (7.5YR 3/1 and 3/2) when dry, dark brown (7.5YR 3/2) when moist; strong very coarse angular blocky breaking to strong medium prismatic structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; 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.

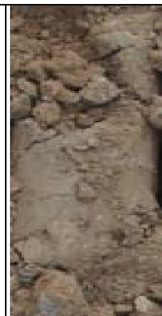
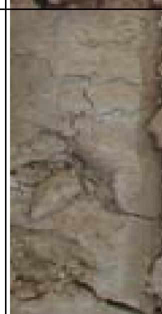
Profile No. 4 – Leighton's Boring CB-3

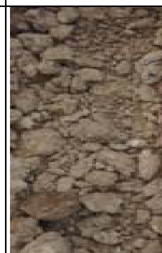
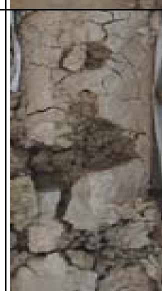
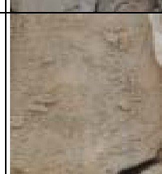
Depth (ft)	Depth (cm)	Horizon Designation		Description
0 – 2	0 – 61	NA		Not available for review. Refer to Leighton's log for details, based on cuttings.
2 – 3.6	61 – 109	Bt1		Gravelly CLAY, clay content decreases downward; very dark grayish brown (10YR 3/2) and brown (7.5YR 4/4) when moist; common moderately 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).

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

12 May 2012

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Certified Professional Soil Scientist No. 24836

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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 ±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

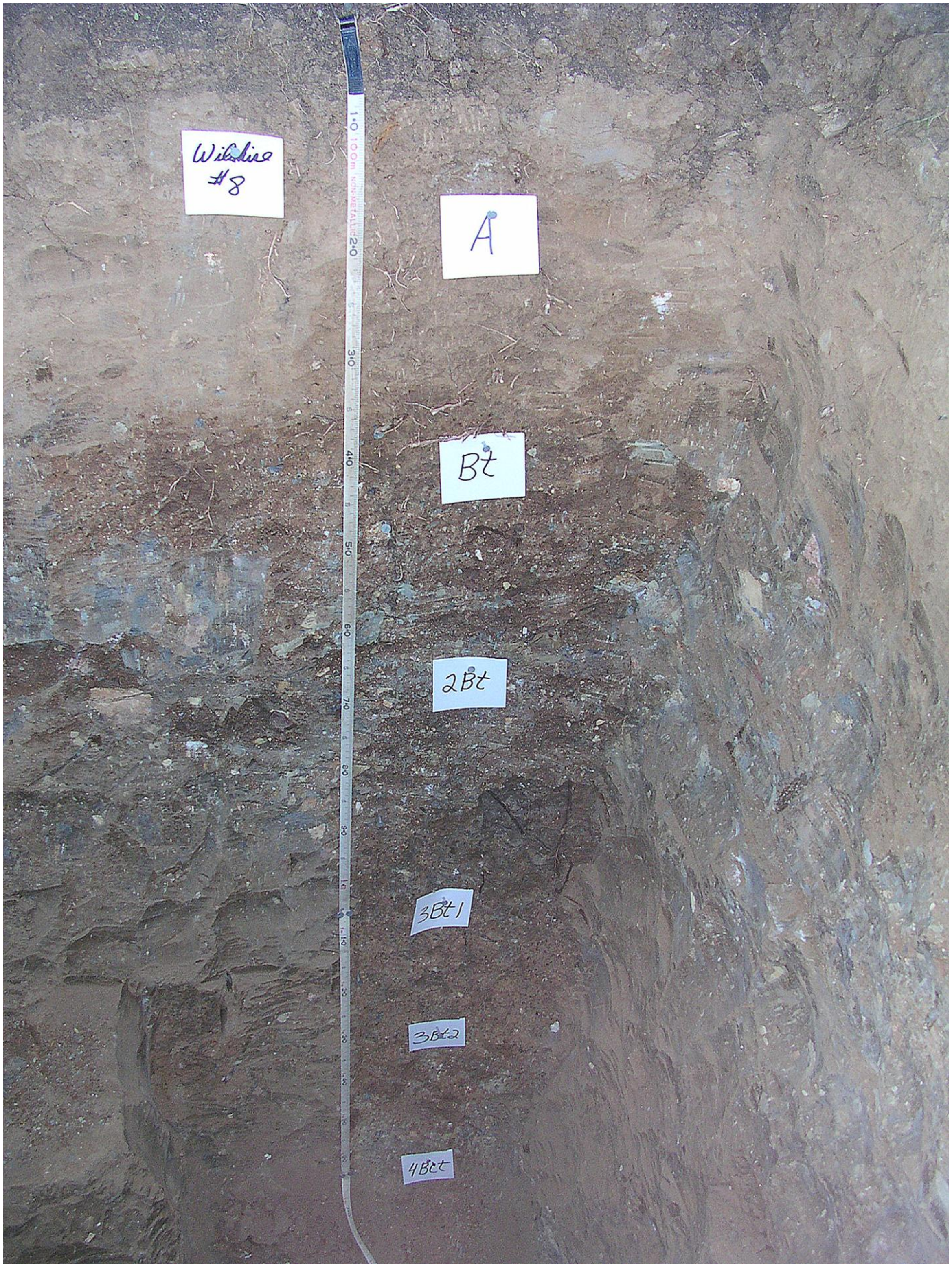

Figure 1. Soil Profile No. 8 in a hand-dug pit along Wilshire Boulevard.

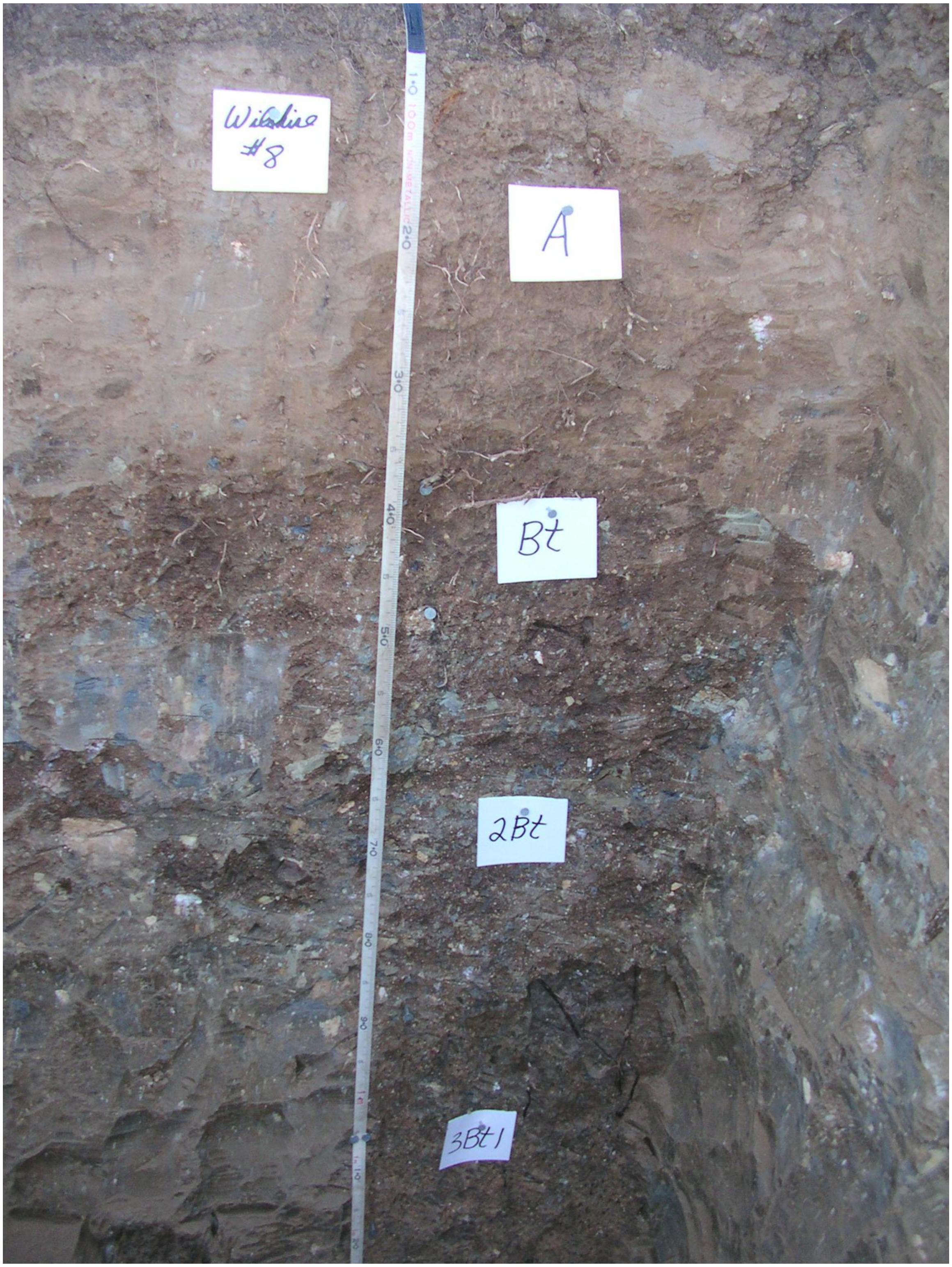

Figure 2. Close-up of the upper 120 cm of Soil Profile No. 8.

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.

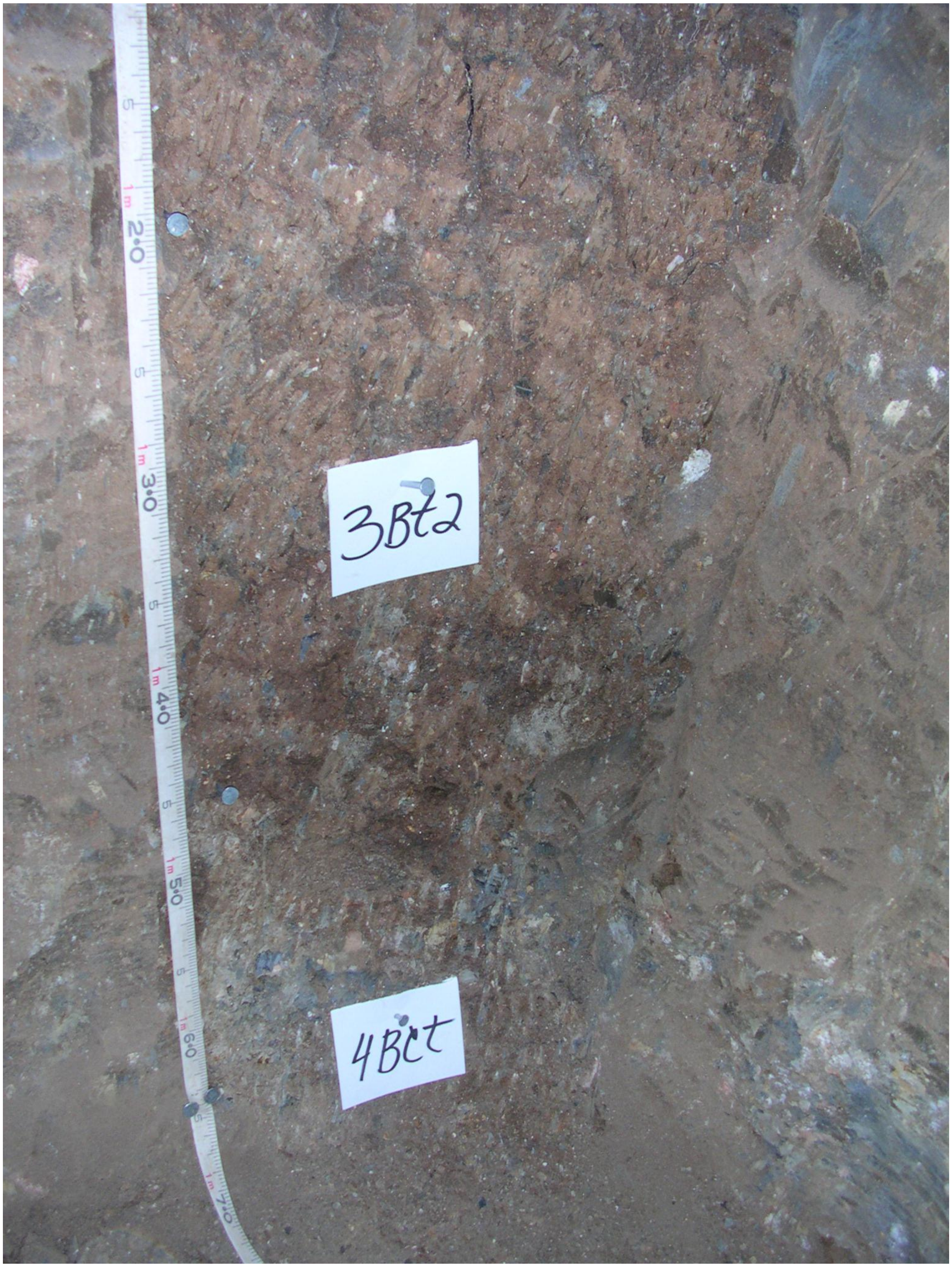

Figure 4. Close-up of the Bt/BCt boundary at the base of the solum in Soil Profile No. 8.

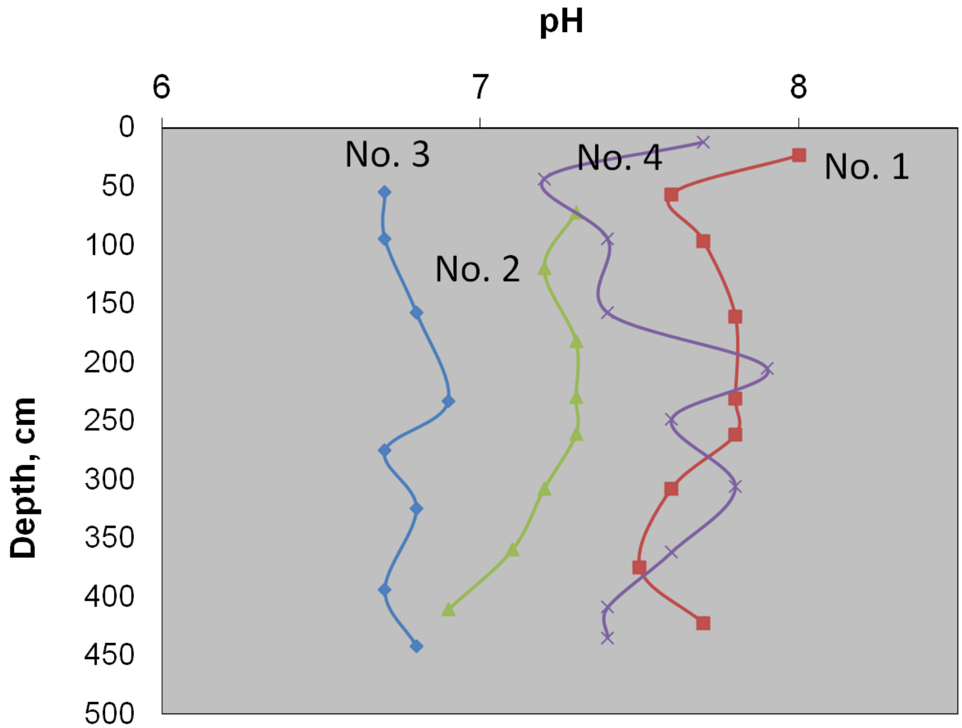

Figure 5. Soil pH of the four profiles studied at Beverly Hills High School. Note that Soil Profile Nos. 2 and 3 are more acidic than either No. 1 or No. 4.

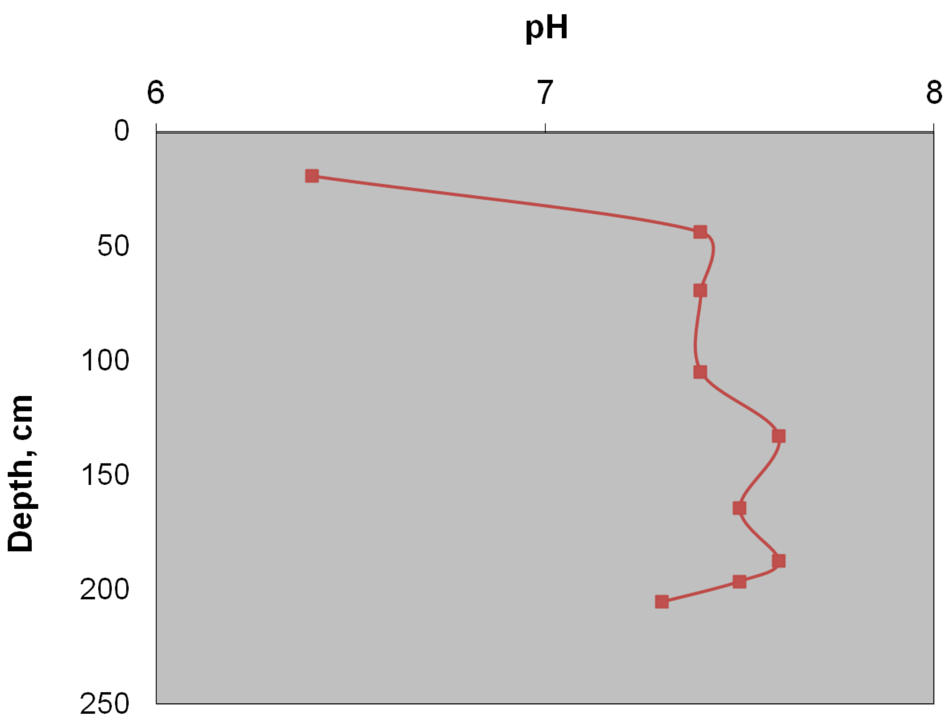

Figure 6. Soil pH for Soil Profile No. 8 at Wilshire Boulevard.

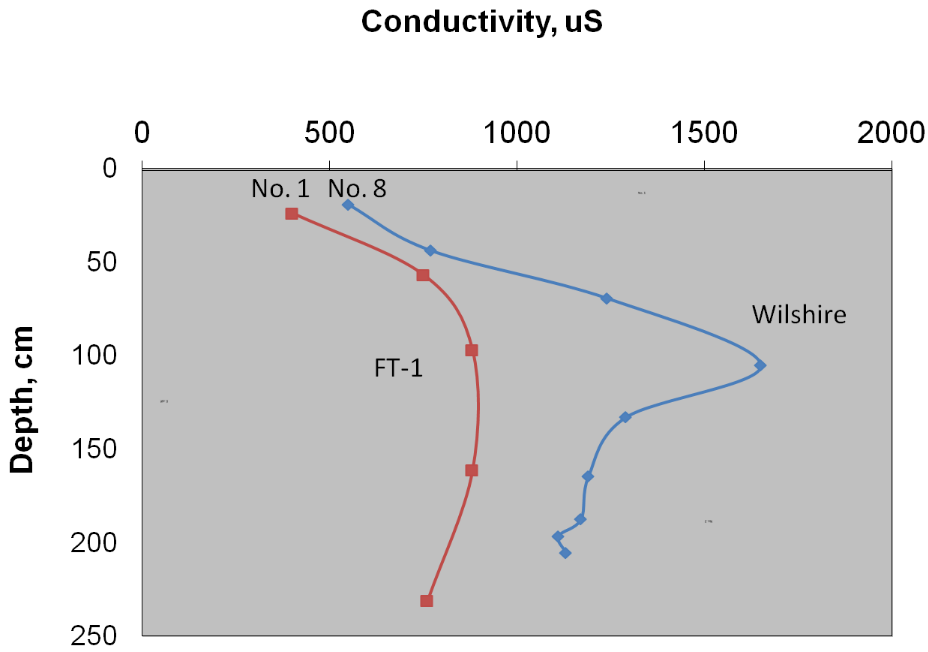

Figure 7. Conductivity in Soil Profile Nos. 1 and 8 from Trench FT-1 at BHHS and the soil pit at Wilshire Boulevard.

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 ±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.

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

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*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 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

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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 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 ±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 $\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. 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.

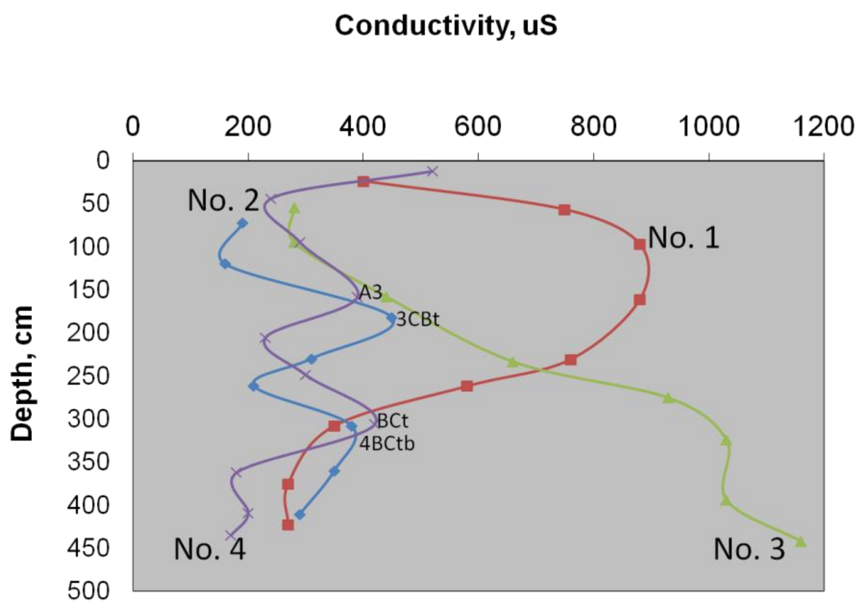


Figure 3. Depth functions for conductivity in Soil Profile Nos. 1, 2, 3, and 4 west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School, Beverly Hills, California. The high salt content in the Bt horizons of No. 1 probably reflects the marine environment and low precipitation 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.

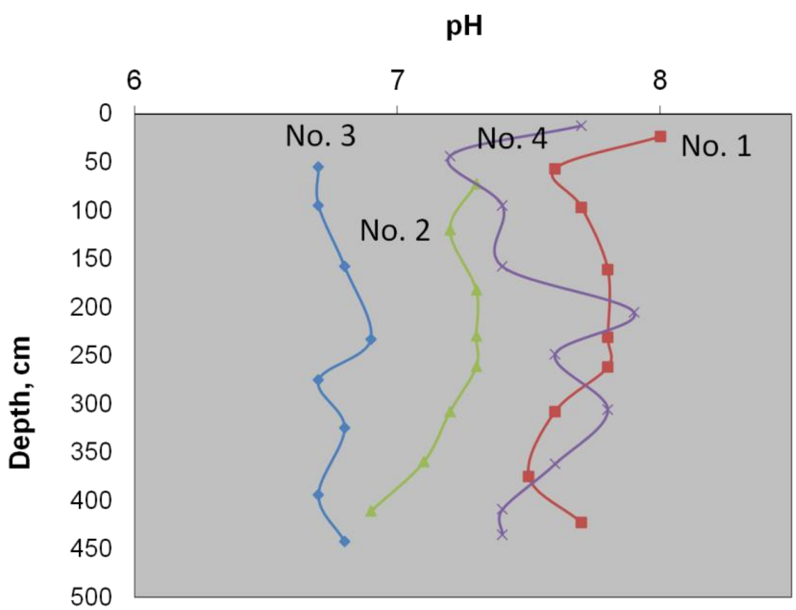


Figure 4. Soil pH of the four soil profiles. Note that Soil Profile Nos. 2 and 3 are more acidic than either the oldest (No. 1) or the youngest (No. 4).

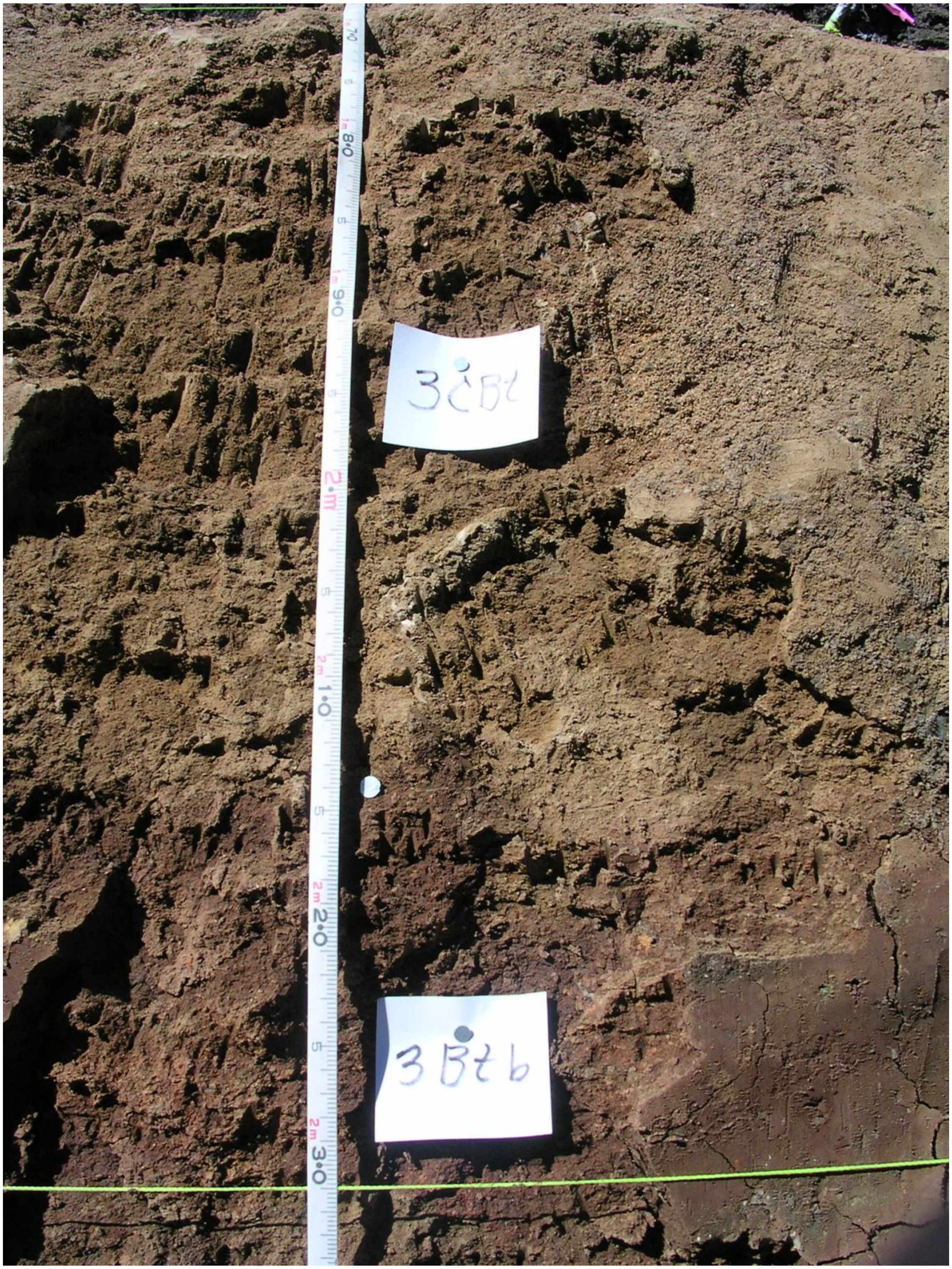


Figure 5. A reddish moderately well developed paleosol (horizon 3Btb) exists beneath the 214-cm depth in Soil Profile No. 2 at Station 0 + 85 in Trench FT-2 west of the West Beverly Hills Lineament, which lies east of Beverly Hills High School. View N.

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.

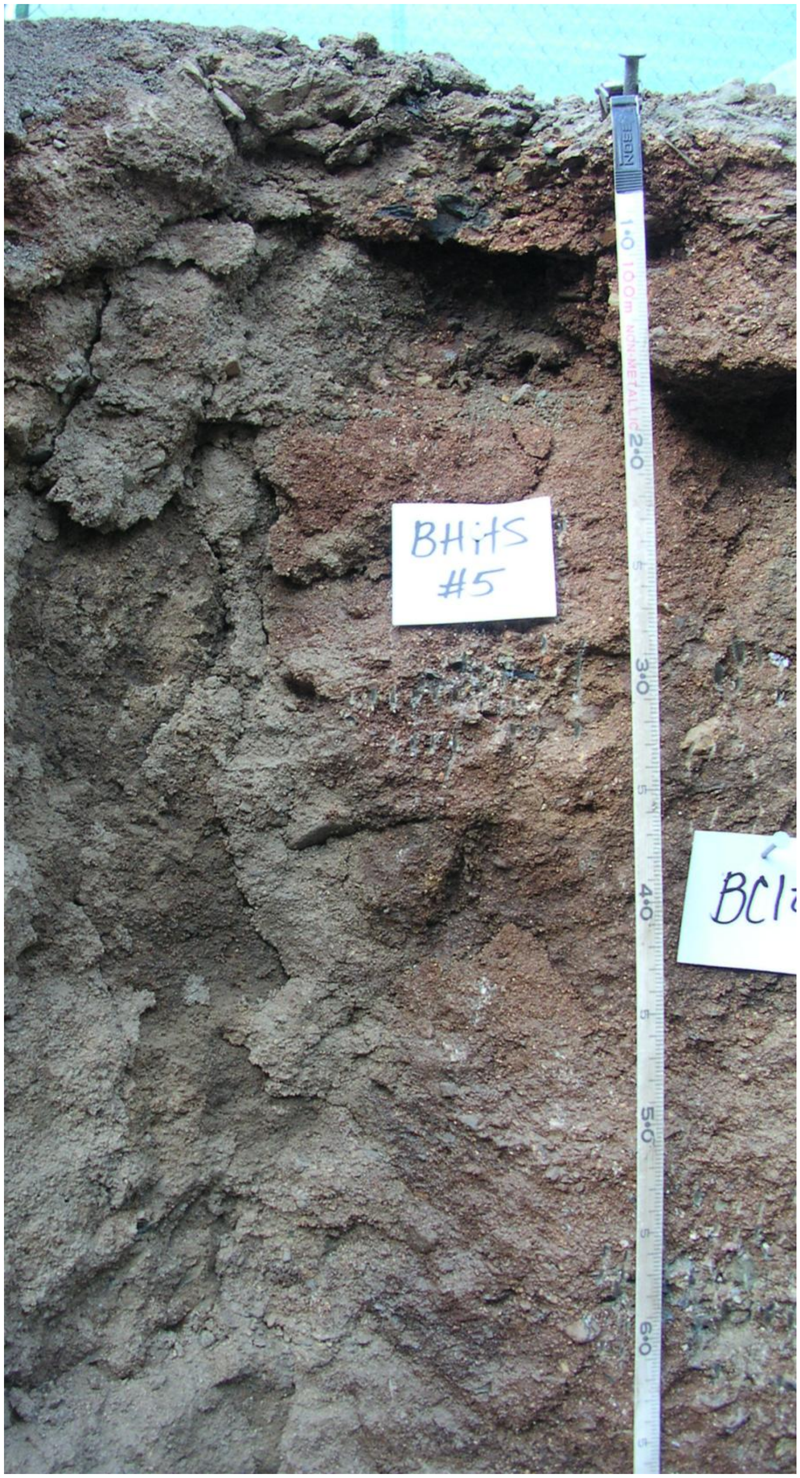


Figure 8. Reddish brown (5YR4/4m) upper portion of Soil Profile No. 5 in Trench FT-3 sampled adjacent to the brown (10YR5/3m) sandy soil tongue.

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 $\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.

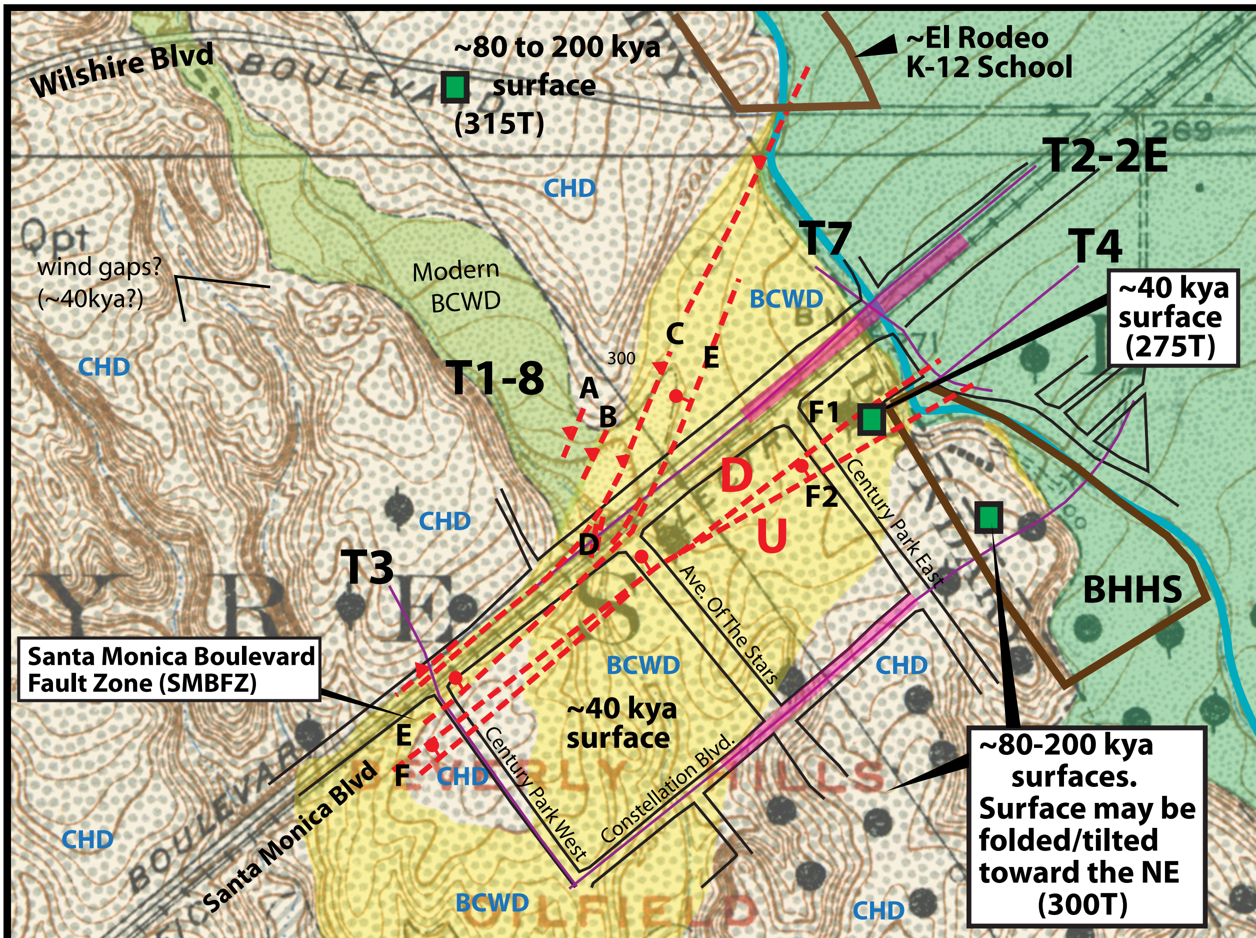
WEATHERING. All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

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.

APPENDIX B – ATTACHED PLATES

Plate 1a	Surface Geology and Fault Map of the Century City Area
Plate 1b	Approximate limits of older Benedict Canyon Wash Deposits
Plate 2a	Surface geology map and Parsons (2011) proposed fault locations, Century City area
Plate 2b	Geologic Fault Map, Century City area
Plate 3	Stratigraphic section of the Cheviot Hills
Plate 4	Fan-terrace surface map, Century City area
Plate 5	Geomorphic cross-section A-A' of fan-terraces
Plate 6	Geomorphic cross-section B-B' of fan-terraces
Plate 7a	Drainage map of the Cheviot Hills – diagram A for Plate 7b
Plate 7b	Drainage map of the Cheviot Hills – diagrams B and C
Plate 8	Constellation Blvd Transect geologic cross-section
Plate 9	Transect 4 geologic cross-section
Plate 10	MACTEC, Parsons & KGS fault map overlay- Fault F & F2
Plate 11	Average strike between secondary upper plate faults and the basal primary oblique reverse fault
Plate 12	The location of the Santa Monica Fault Zone and the Santa Monica Blvd Fault Zone, Cheviot Hills area
Plate 13	Geomorphic terrace map of the Cheviot Hills showing surface folding
Plate 14	Cross-section along Constellation Blvd showing true scale of near surface folding, Century City area
Plate 15	Folding data, Century City area
Plate 16	Diagrammatic cross-section of the Santa Monica Fault Zone, Century City area
Plate 17	Releasing bend model in the Santa Monica Blvd Fault Zone, Century City area
Plate 18	Conceptual model of the interactions of the Santa Monica and Newport-Inglewood Fault Zones, Century City area
Plate KGS-T1	Modified CPT and Boring Cross Section of Transects 1 & 8 of Parsons (2011), Century City Area, City of Los Angeles
Plate KGS-T2	Modified CPT and Boring Cross Section of Transects 2 & 2E of Parsons (2011), Century City Area, City of Los Angeles
Plate KGS-T4	Modified CPT and Boring Cross Section of Transect 4 of Parsons (2011), Century City Area, City of Los Angeles
Plate KGS-T7	Modified CPT and Boring Cross Section of Transect 7 of Parsons (2011), Century City Area, City of Los Angeles



Base topographic-Geologic map from Hoots (1931).

SYMBOL DESCRIPTIONS

Approximate limits of younger Benedict Canyon Wash Deposits (<~40,000 years old).

BCWD — Approximate limits of older Benedict Canyon Wash Deposits. Upper-most sediments are a minimum of ~40,000 years old.

CHD — Approximate limits of Cheviot Hills Deposits. Upper fan-terrace surfaces (315T and 300T, see notes) are 150,000 to 200,000 years old.

D / U — Approximate surface projection location of faults identified during this study. Balls and barbs for normal and reverse apparent displacement faults. D - down, U - Up sides.

T7 — Approximate location of geologic transect by Parsons (2012).

BHHS — Beverly Hills High School

Approximate location of soil with estimated age.

Proposed Metro Stations on Santa Monica Blvd, and Constellation Blvd.

Notes:

Based on the existing soil age data, nearly all of the sediments exposed at the surface within the Cheviot Hills are 40,000 to 200,000 years old.

The 300T and 315T fan-terraces are shown on Plate ES-4 and represent average elevations of the preserved surfaces.

0 scale 1000 feet

Kenney GeoScience

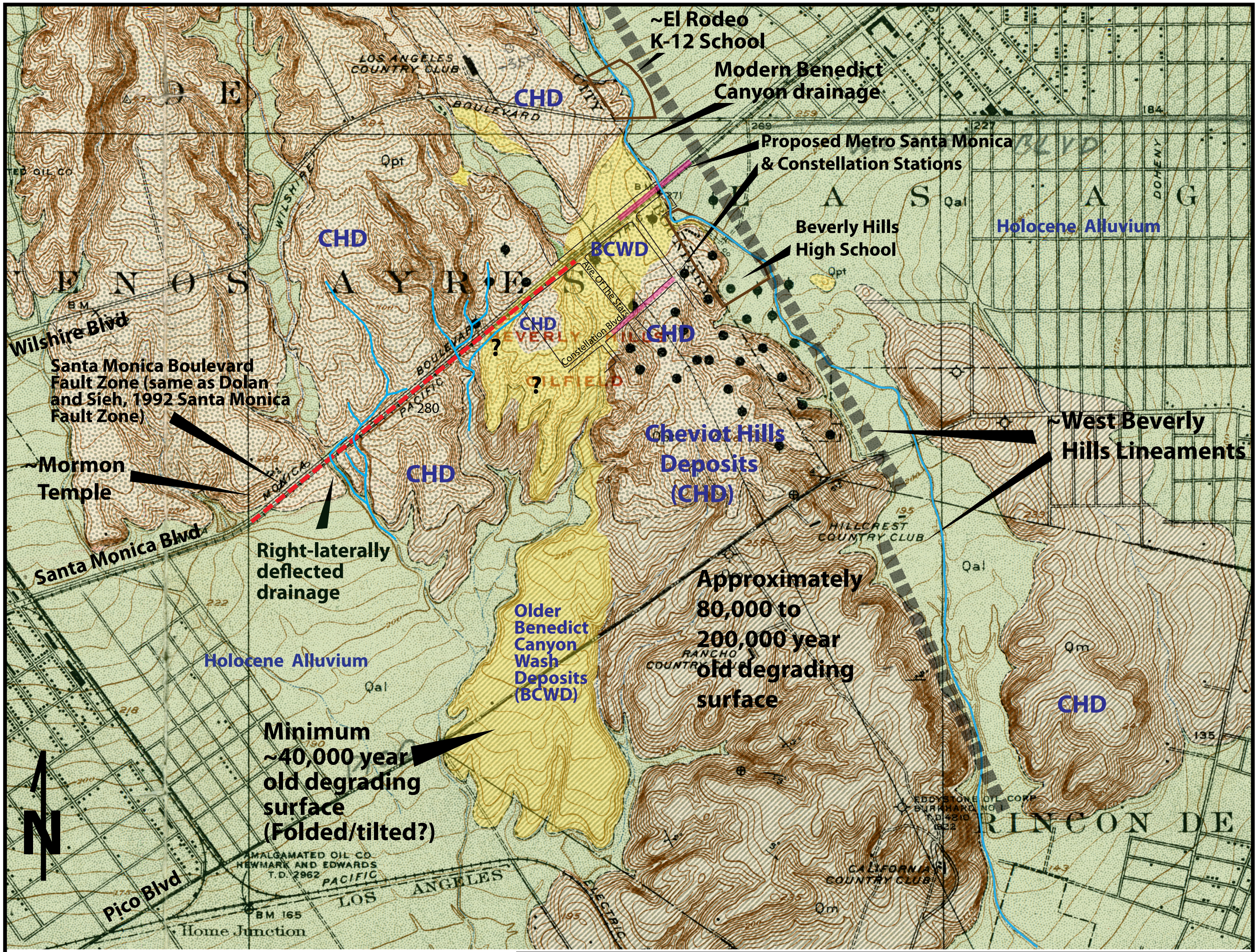
CLIENT: HILL, FARRER & BURRILL LLP

PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Surface geology and fault map of the Century City area

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-1a



Base Geologic map from Hoots (1931).

0 scale 1000
feet

Kenney GeoScience

CLIENT:
HILL, FARRER & BURRILL LLP

PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Approximate limits of older Benedict Canyon Wash Deposits

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-1b

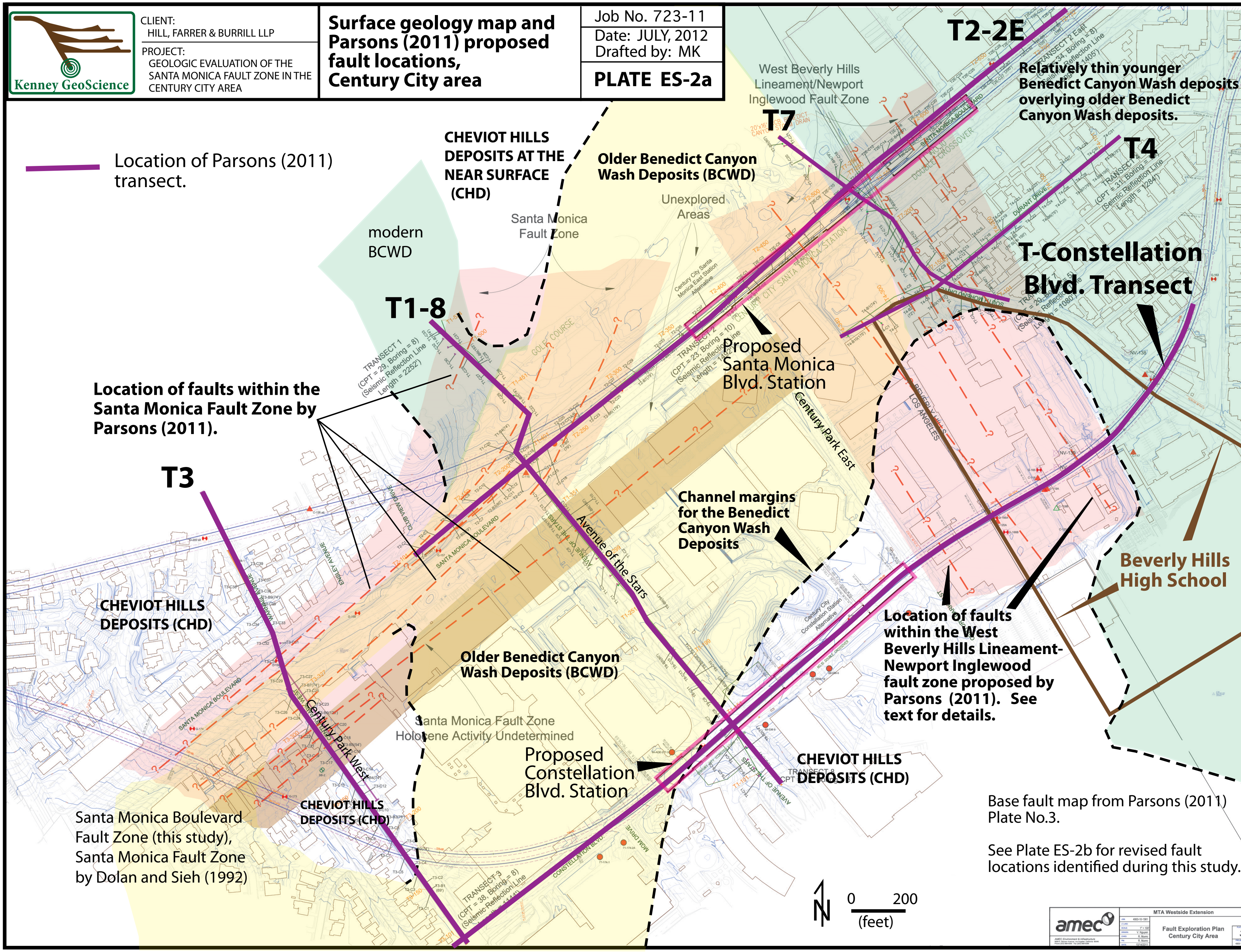
CLIENT:
HILL, FARRER & BURRILL LLP

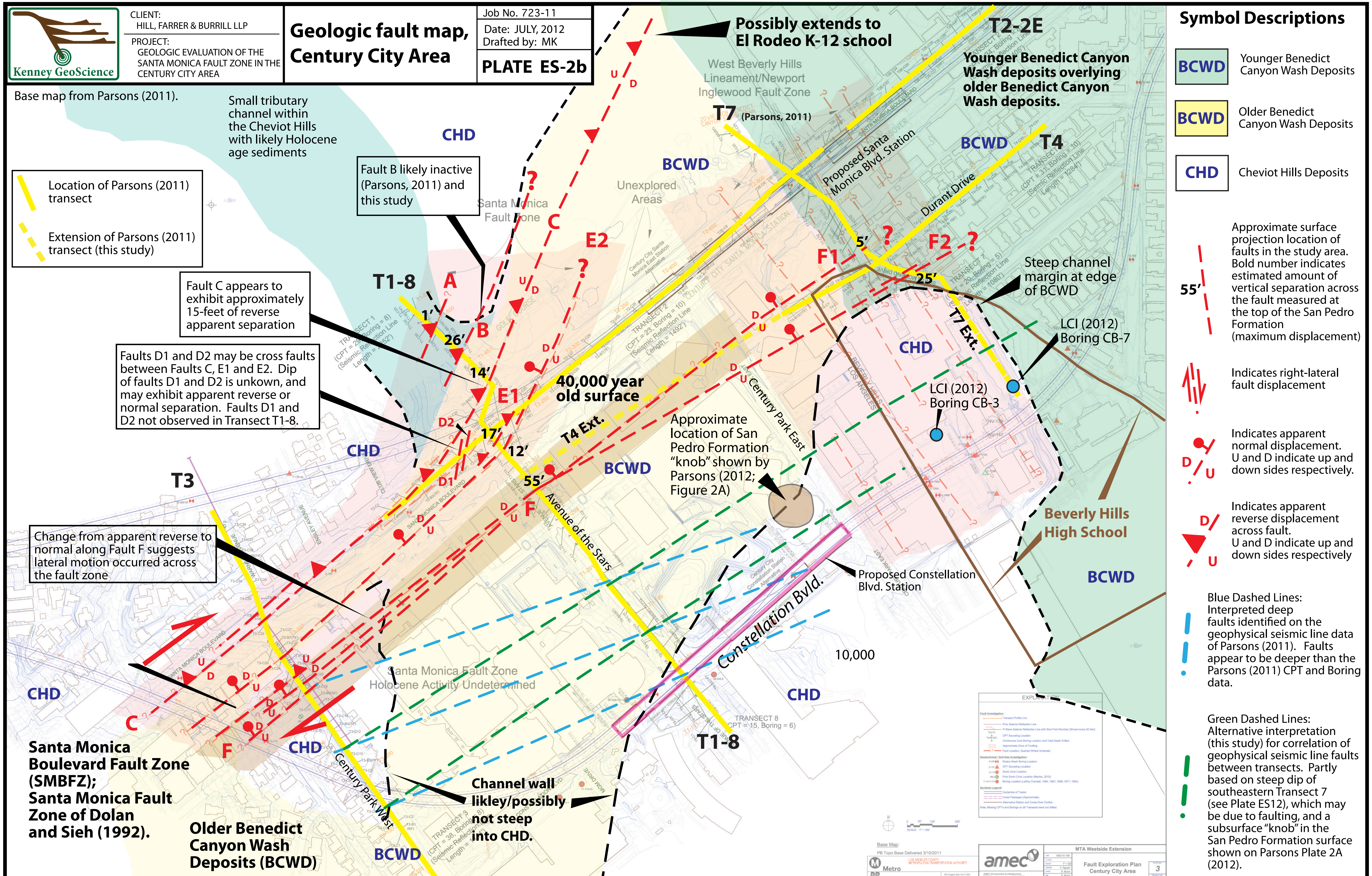
PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Surface geology map and Parsons (2011) proposed fault locations, Century City area

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-2a





Kenney GeoScience
CLIENT: HILL, FARRER & BURRILL LLP
PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA
Geologic fault map, Century City Area
Job No. 723-11
Date: JULY, 2012
Drafted by: MK
PLATE ES-2b
Base map from Parsons (2011).
Small tributary channel within the Cheviot Hills with likely Holocene age sediments
Location of Parsons (2011) transect
Extension of Parsons (2011) transect (this study)
Fault B likely inactive (Parsons, 2011) and this study
Santa Monica Fault Zone
Fault C appears to exhibit approximately 15-feet of reverse apparent separation
Faults D1 and D2 may be cross faults between Faults C, E1 and E2. Dip of faults D1 and D2 is unkown, and may exhibit apparent reverse or normal separation. Faults D1 and D2 not observed in Transect T1-8.
Change from apparent reverse to normal along Fault F suggests lateral motion occurred across the fault zone
Santa Monica Boulevard Fault Zone (SMBFZ); Santa Monica Fault Zone of Dolan and Sieh (1992).
Older Benedict Canyon Wash Deposits (BCWD)
Channel wall likley/possibly not steep into CHD.
Santa Monica Fault Zone Holocene Activity Undetermined
Possibly extends to El Rodeo K-12 school
West Beverly Hills Lineament/Newport Inglewood Fault Zone
Unexplored Areas
T2-2E
Younger Benedict Canyon Wash deposits overlying older Benedict Canyon Wash deposits.
T7 (Parsons, 2011)
Proposed Santa Monica Blvd. Station
Durant Drive
T4
40,000 year old surface
T4 Ext.
T7 Ext.
Steep channel margin at edge of BCWD
LCI (2012) Boring CB-7
LCI (2012) Boring CB-3
Approximate location of San Pedro Formation "knob" shown by Parsons (2012; Figure 2A)
Century Park East
Avenue of the Stars
Century Park West
Constellation Blvd.
Proposed Constellation Blvd. Station
Beverly Hills High School
10,000
T1-8
T3
A
B
C
D1
D2
E1
E2
F
F1
F2
1'
26'
14'
17'
12'
55'
5'
25'
CHD
BCWD
Symbol Descriptions
BCWD Younger Benedict Canyon Wash Deposits
BCWD Older Benedict Canyon Wash Deposits
CHD Cheviot Hills Deposits
Approximate surface projection location of faults in the study area. Bold number indicates estimated amount of vertical separation across the fault measured at the top of the San Pedro Formation (maximum displacement)
Indicates right-lateral fault displacement
Indicates apparent normal displacement. U and D indicate up and down sides respectively.
Indicates apparent reverse displacement across fault. U and D indicate up and down sides respectively
Blue Dashed Lines: Interpreted deep faults identified on the geophysical seismic line data of Parsons (2011). Faults appear to be deeper than the Parsons (2011) CPT and Boring data.
Green Dashed Lines: Alternative interpretation (this study) for correlation of geophysical seismic line faults between transects. Partly based on steep dip of southeastern Transect 7 (see Plate ES12), which may be due to faulting, and a subsurface "knob" in the San Pedro Formation surface shown on Parsons Plate 2A (2012).
amec
MTA Westside Extension
Fault Exploration Plan Century City Area

GEOLOGIC UNIT DESIGNATION	SYMBOL	DESCRIPTION	ESTIMATED AGE
	Af	Artificial fill	
Benedict Canyon Wash Deposits **BCWD** — Younger BCWD	**Qf/Qfo**	Quaternary alluvium (late to latest Pleistocene) as defined by Parsons. Drawn in some areas where the original Parsons designation of Qf/Qfo was slightly modified herin. Unit Qf/Qfo likely includes uppermost members of ancient BCWDAT.	~40,000 years old (Soil Tectonics, 2012b). Terrace elevation approximately 275 to 280 msl
Older BCWD	**A**	Soil profile marker horizon within Benedict Canyon Wash Deposits.	~134,000 years old (Soil Tectonics, 2012b)
			~150,000 years old erosion surface created during Marine Isotope Stage 6
Cheviot Hills Deposits **CHD**	**"300T" terrace surface**	Abandoned geomorphic fan-terrace surfaces that locally ranges in elevation between approximately 285 to 350+ feet above msl (see Plate ES-4).	Minimum ~80,000 year old soil (Soil Tectonics, 2012a) but sediments may be as old as 150,000 to 200,000 years
	B	Soil profile marker horizon that typically exists in the uppermost section of the Cheviot Hills Deposits. Type local is in Boring T2E-B1. In most places the upper soil horizons have been eroded away.	~500,000 years old as correlated to dated soils in LCI (2012) and ECI (2012). (B and C)
	C	Soil profile marker horizon with strong calcium carbonate. Type local identified in Boring T7-B2.	
	D	Soil profile marker horizon with distincive reddish brown color variations identified by Parsons (2011) as "spotted" and by LCI (personal communication) as "praprika", likely due to mottling. See Transect 7 (Plates KGS-7).	
			Erosion Surface
San Pedro Sequence **SPS**	**E**	Soil profile marker horizon with manganese oxide and/or carbonate.	At LCI (2012) Boring CB-3, these soils likely do not exist due to erosion and thus were not dated (E and F)
	F	Soil profile marker horizon with manganese oxide and/or carbonate. Typically overlies unit Qfob.	
	Qfob	Silty sand with clay and abundant carbonate. Identified by Parsons (2011)	Minimum ~574,000 years old as correlated to dated soils in LCI (2012) and ECI (2012). (Qfob and Qeb)
	Qeb	Clay with abundant carbonate. Identified by Parsons (2011) and based on their data unit Qeb is likely comformable with the underlying San Pedro Formation. Unit is likely terrestrial.	
	Qsp	San Pedro Formation. Marine deposits with abundant shells and distinctive dark colors and well sorted clay, sand, and gravel layers.	Minumum 600,000 years old (LCI, 2012; ECI, 2012).

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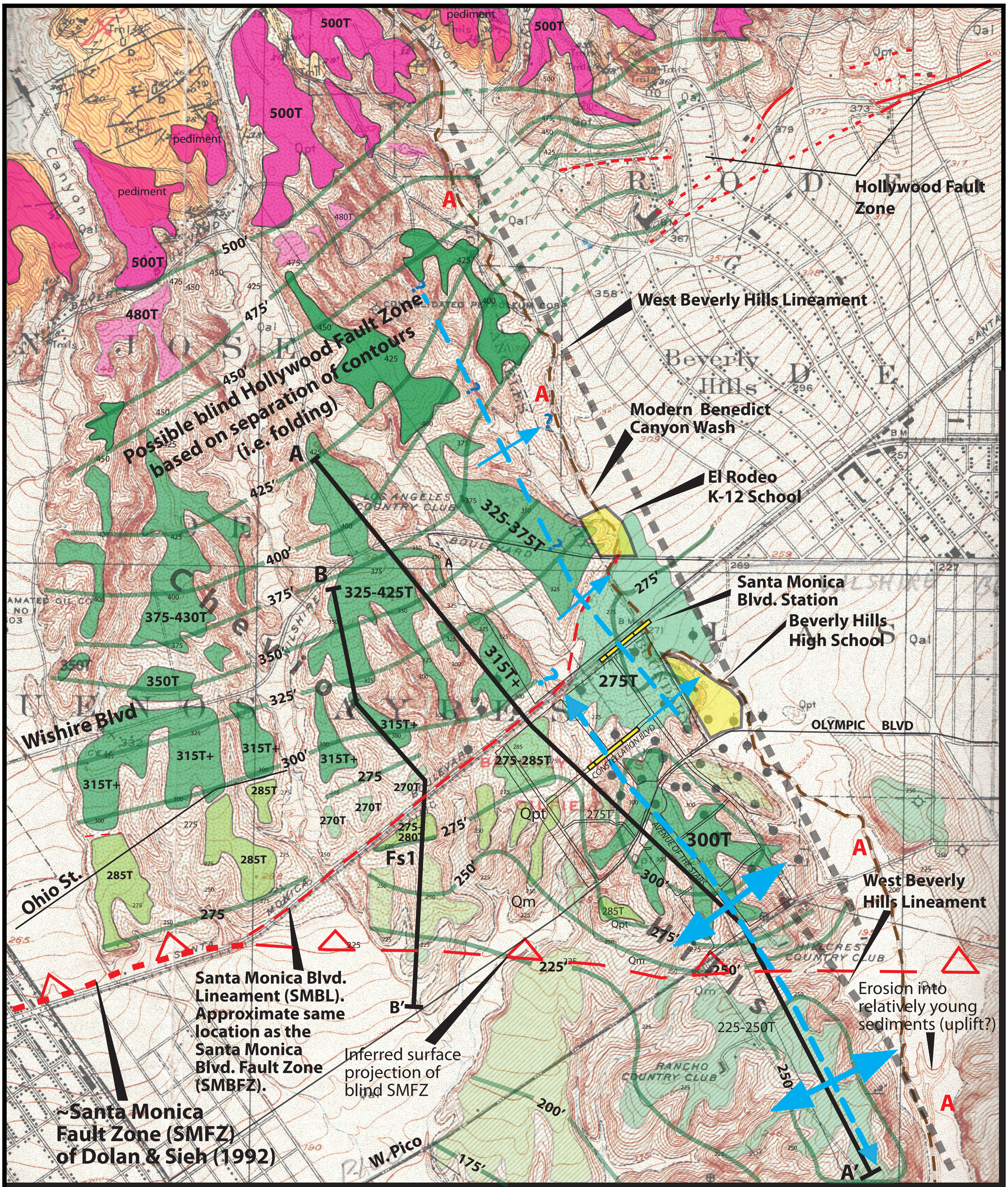
PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Stratigraphic section of the Cheviot Hills

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-3



Base topographic-Geologic map from Hoots (1931).

SYMBOL DESCRIPTIONS

Approximate location of the Santa Monica Fault Zone per Dolan and Sieh (1992) west of the Cheviot Hills and Hollywood Fault Zone. Barb indicates inferred reverse displacement with dip to the north.

Approximate location of the Santa Monica Blvd. Lineament (SMBL, this study) and also the Santa Monica Fault Zone by Dolan and Sieh (1992). The geomorphic (topographic) SMBL is approximately in the same general location as the Santa Monica Boulevard Fault Zone (SMBFZ, this study).

Possible buried location of the Santa Monica Fault Zone (SMFZ).

290T+ Approximate limits of degraded/dissected remnant fan-terrace surfaces (fluvial). Number provides approximate average elevation of surface.

275 Generalized elevations extropolated over degraded terrace surfaces. Number in bold indicates approximate elevation in feet.

B B' Location of Cross Sections A-A' and B-B' (see Plates ES-5 and 6).

A General locations where Benedict Canyon Wash is antecedent.

Approximate anticline fold axis

Approximate location of monocline fold axis

5000 4000 3000 2000 1000 0

Scale (feet) - 1:24,000

Contour interval 5 and 25 feet, datum is mean sea level.

Base survey data collected from 1923 to 1925 by the USGS.

N

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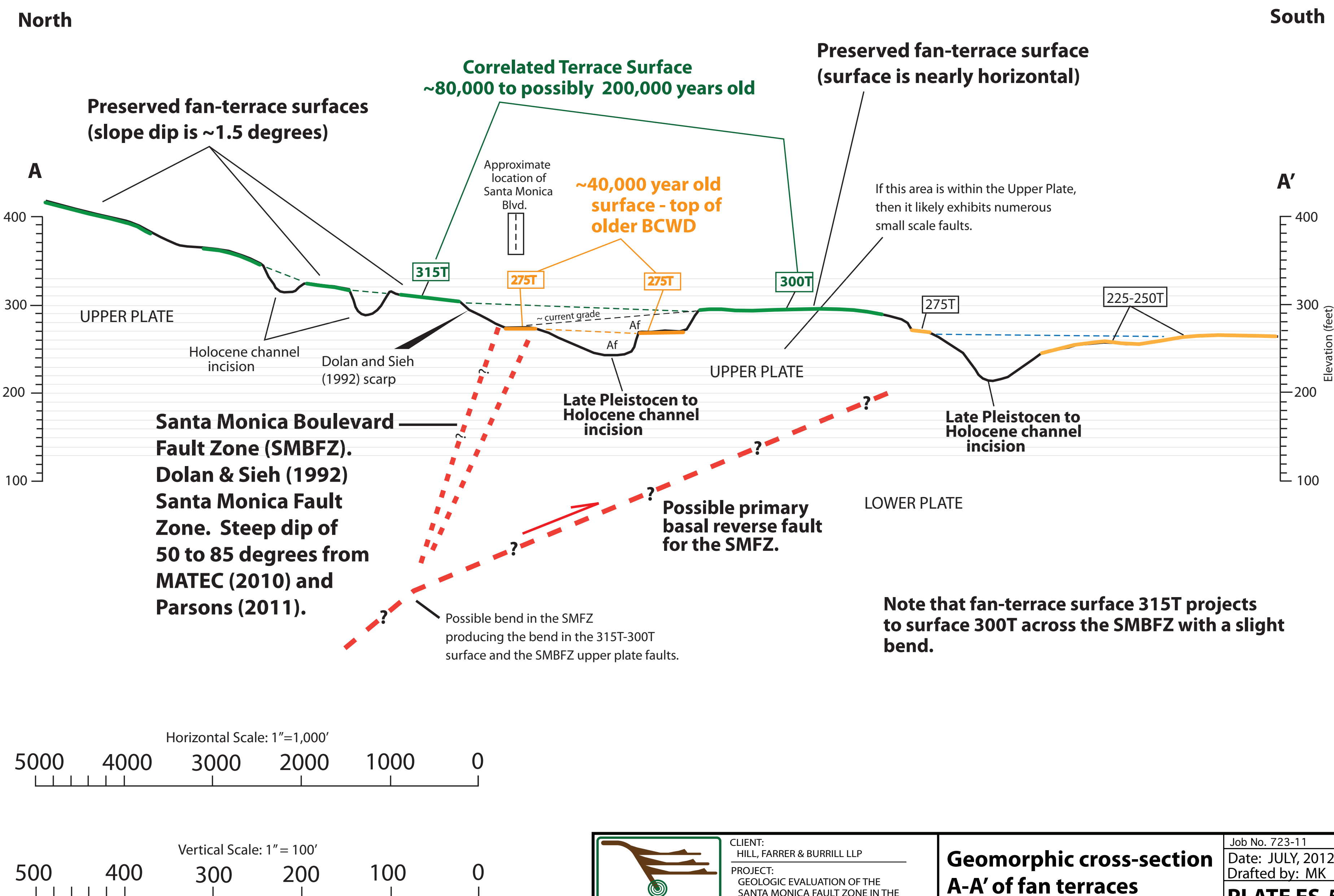
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Fan-terrace surface map, Century City area

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-4



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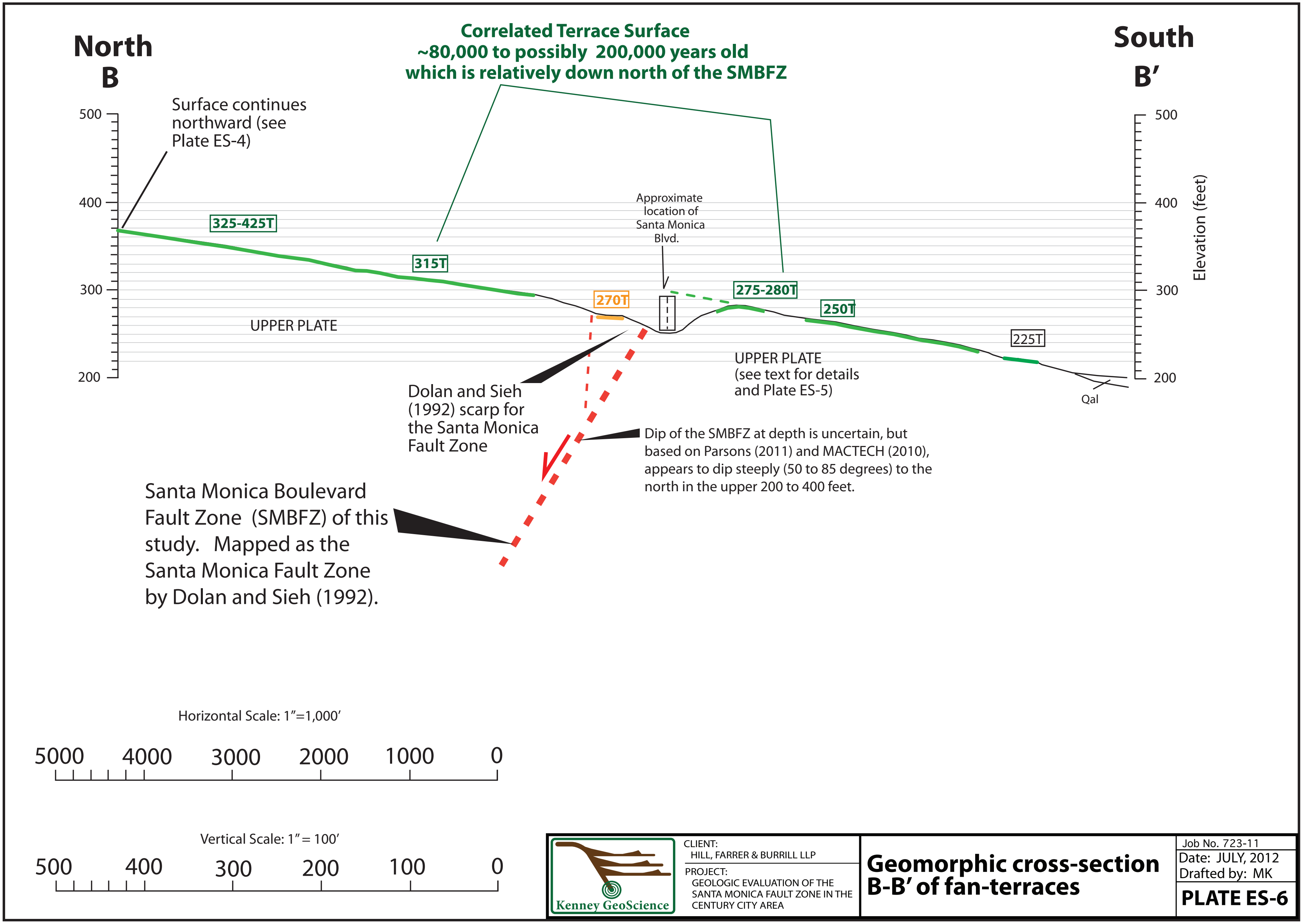
HILL, FARRER & BURRILL LLP

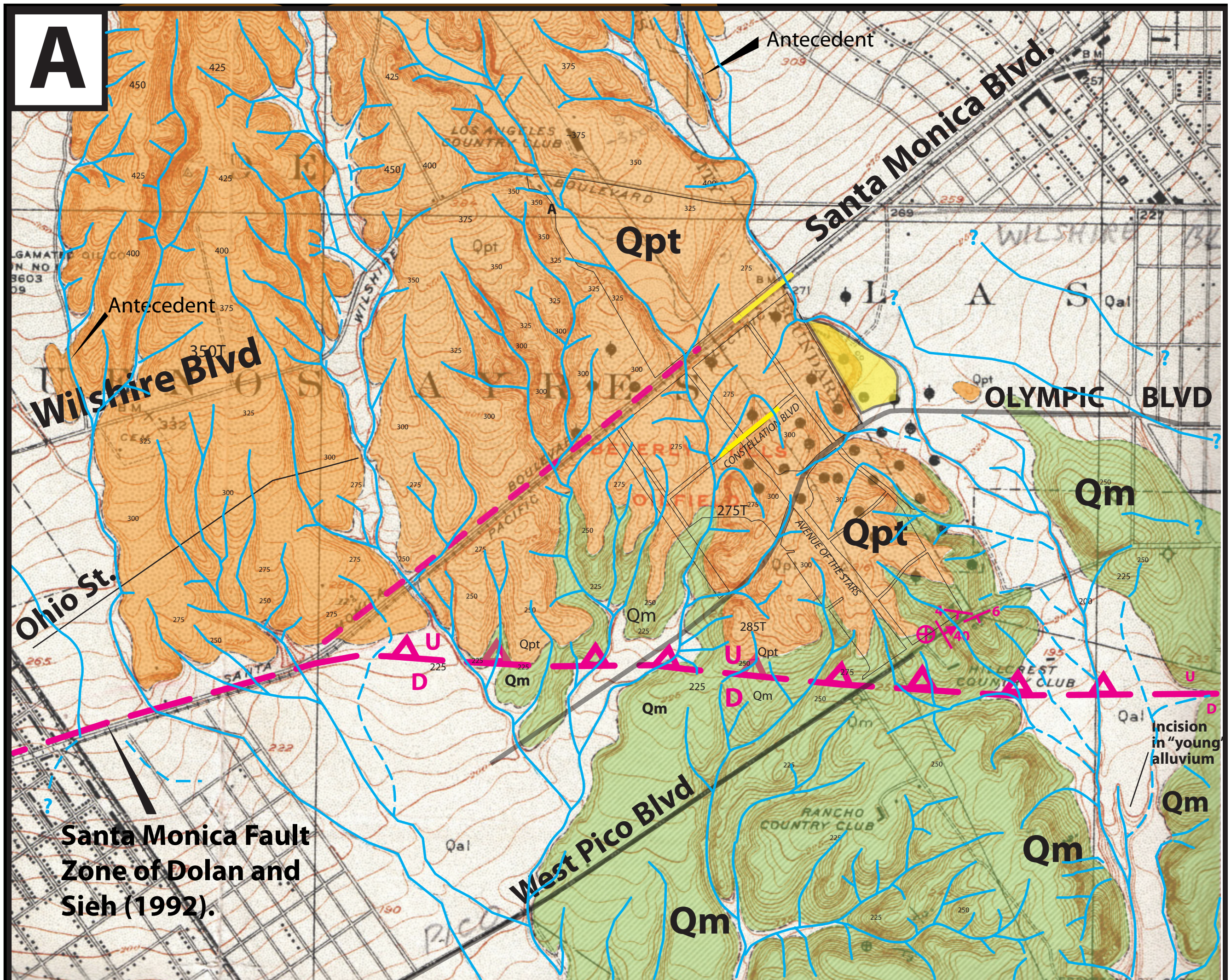
PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Geomorphic cross-section A-A' of fan terraces

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-5


North
B
South
B'
Correlated Terrace Surface
~80,000 to possibly 200,000 years old
which is relatively down north of the SMBFZ
Surface continues
northward (see
Plate ES-4)
500
400
300
200
Elevation (feet)
325-425T
315T
270T
275-280T
250T
225T
Approximate
location of
Santa Monica
Blvd.
UPPER PLATE
UPPER PLATE
(see text for details
and Plate ES-5)
Qal
Dolan and Sieh
(1992) scarp for
the Santa Monica
Fault Zone
Dip of the SMBFZ at depth is uncertain, but
based on Parsons (2011) and MACTECH (2010),
appears to dip steeply (50 to 85 degrees) to the
north in the upper 200 to 400 feet.
Santa Monica Boulevard
Fault Zone (SMBFZ) of this
study. Mapped as the
Santa Monica Fault Zone
by Dolan and Sieh (1992).
Horizontal Scale: 1"=1,000'
5000 4000 3000 2000 1000 0
Vertical Scale: 1" = 100'
500 400 300 200 100 0
Kenney GeoScience
CLIENT:
HILL, FARRER & BURRILL LLP
PROJECT:
GEOLOGIC EVALUATION OF THE
SANTA MONICA FAULT ZONE IN THE
CENTURY CITY AREA
Geomorphic cross-section
B-B' of fan-terraces
Job No. 723-11
Date: JULY, 2012
Drafted by: MK
PLATE ES-6



Symbol Descriptions

Approximate center of drainage wash

Santa Monica Boulevard Lineament (SMBL). Called the Santa Monica fault zone (SMFZ) by Dolan & Sieh (1992) and the Santa Monica Boulevard fault zone within this study (SMBFZ).

U D Postulated location of surface projection of the basal reverse Santa Monica Fault Zone. U and D for side that goes Up and Down respectively.

4 Strike and dip of bedding (from Hoots, 1931).

Horizontal bedding (from Hoots, 1931)

40 Approximate strike, dip of small scale fault exhibiting normal apparent offset (i.e. less than 5-feet).

Qpt Limits of Quaternary alluvial plain, stream and marine deposits (from Hoots, 1931).

Qm Limits of Quaternary marine deposts (from Hoots, 1931).

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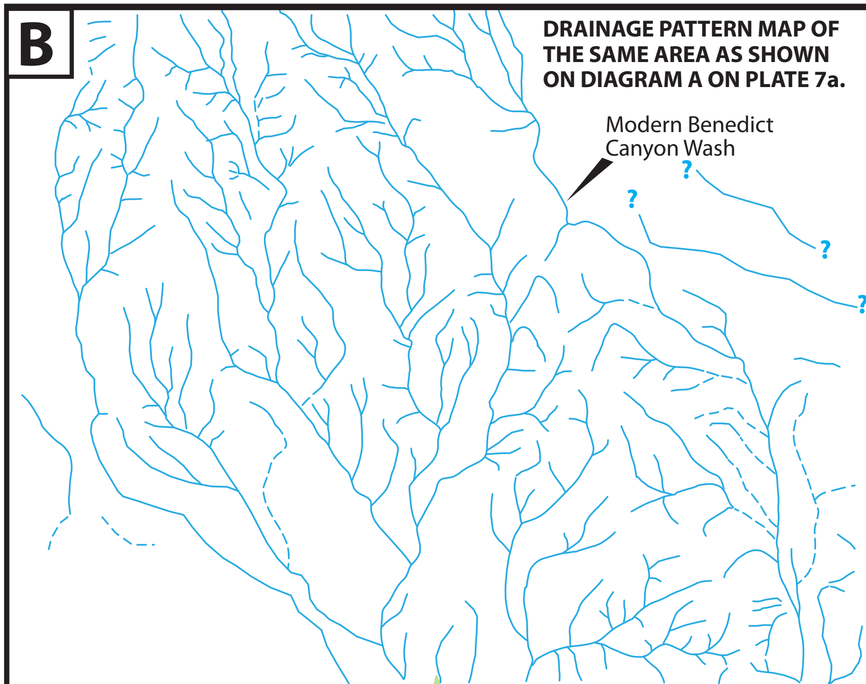
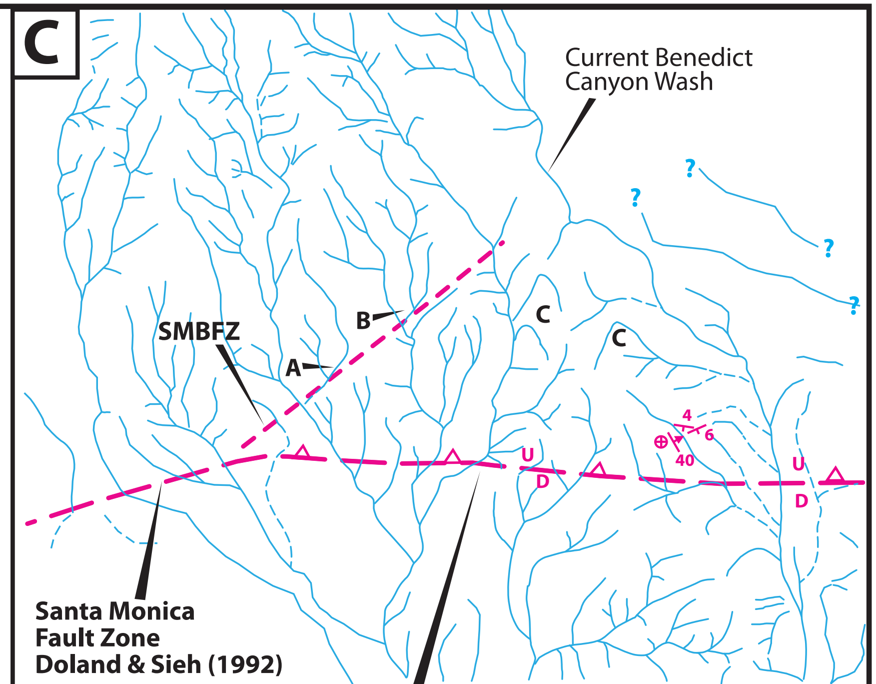
PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Drainage map of the Cheviot Hills - diagram A for Plate 7b

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-7a





Inferred blind Santa Monica Fault Zone

Symbol Descriptions

Approximate center of drainage wash. Dashed where uncertain

U
D
Postulated location of surface projection of the basal reverse Santa Monica Fault Zone. U and D for up and down sides.

4
Strike and dip of bedding (from Hoots, 1931).

Horizontal bedding (from Hoots, 1931).

40
Approximate strike & dip, and location of small scale fault exhibiting normal apparent offset (from G. Butler).

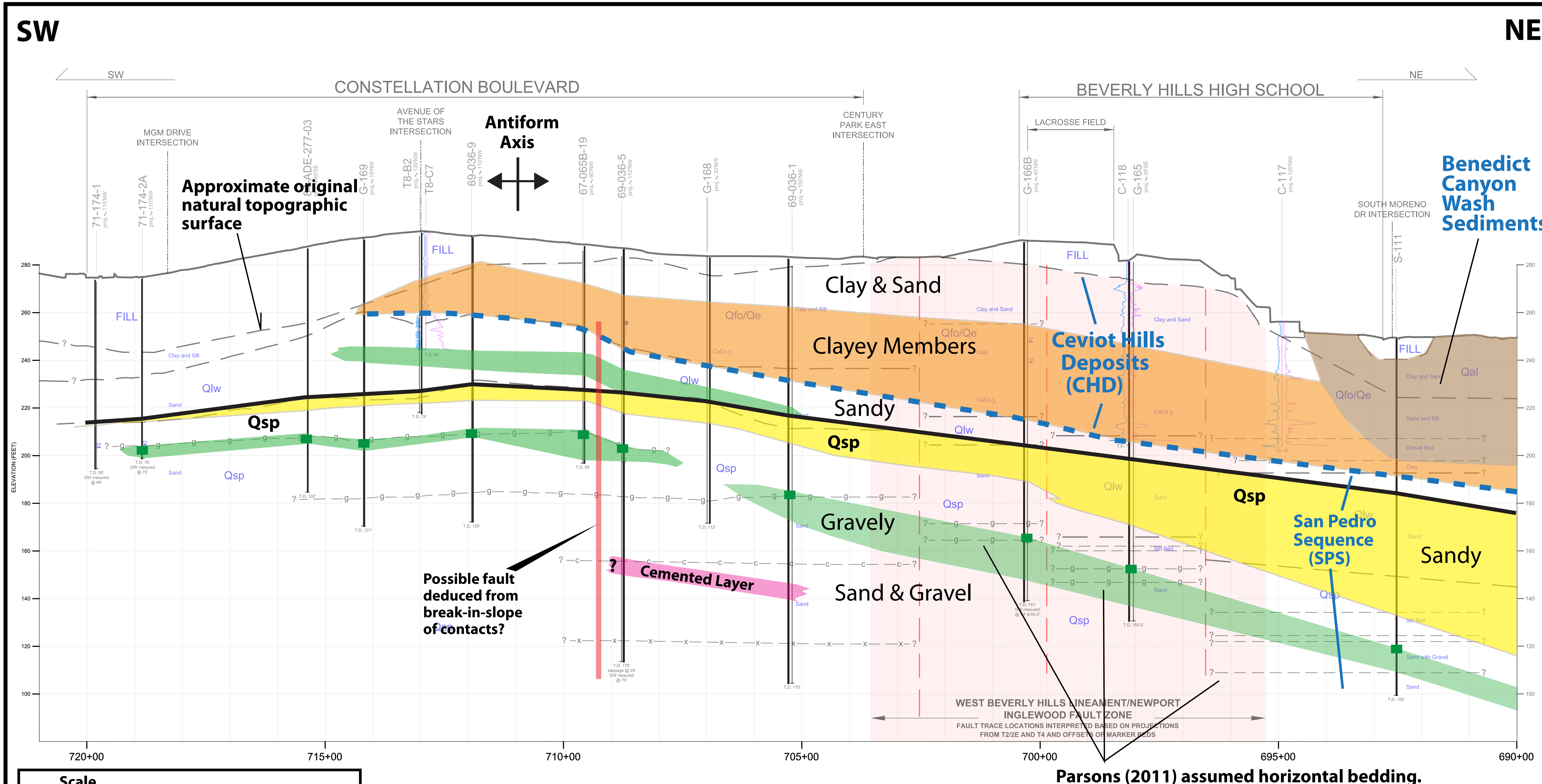
Drainage locations **A** and **B** in diagram C show apparent right-lateral deflection across the Santa Monica Boulevard Fault Zone (SMBFZ).

Drainage **A** essentially flows into an elevated hill as it crosses the SMBFZ (see Plate ES-7a). This suggests that the SMBFZ exhibited a component of right-lateral displacement.

Drainage **B** may be a right-laterally deflected drainage, or simply deflected by artificial fill and grading associated with construction of the railroad line prior to development of the Hoots, 1931 topographic map (see Plate ES-7a).

Drainages in area **C** exhibit "hook" turns possibly due to late Quaternary Folding (see text for details).

Kenney GeoScience	CLIENT: HILL, FARRER & BURRILL LLP PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	**Drainage map of the Cheviot Hills - diagrams B and C**	Job No. 723-11 Date: JULY, 2012 Drafted by: MK **PLATE ES-7b**



Scale

VERTICAL SCALE: 1" = 20'-0"

HORIZONTAL SCALE: 1" = 100'-0"

Scale:
Vertical = 10XHorizontal

Approximate upper contact of the San Pedro Sequence (SPS)

Approximate upper contact of the San Pedro Formation (Qsp)

See Plate ES-2a for Constellation Transect Location

Base map from:

amec — AMEC Environment & Infrastructure

Geologic Section

CONSTELLATION PROFILE
WEST BEVERLY HILLS LINEAMENT/NEWPORT INGLEWOOD FAULT ZONE PROFILE ALONG CONSTELLATION BOULEVARD ALTERNATIVE STATION 690+00 TO 730+00
Century City, Los Angeles, California

PLATE NO. 9

Kenney GeoScience

CLIENT:
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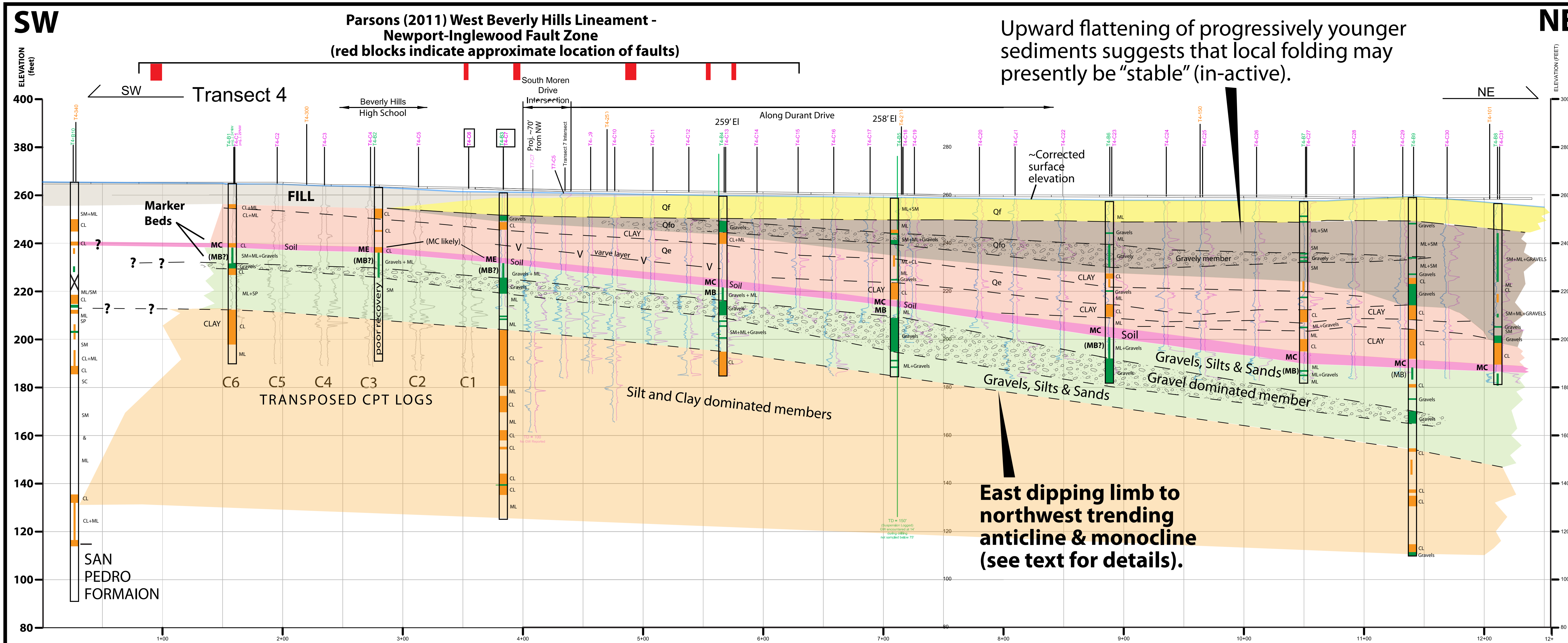
PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Constellation Blvd Transect geologic cross-section

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-8



Geologic Descriptions

Clay (CL or CH)

Unit contains clay

Gravel member

Unit contains gravel

Silt (ML) - not colored

Note: **Proposed WBHL-Newport Inglewood faults likely do not exist if the sedimentary units are assumed to dip toward the NE.**

Modified from Parsons report dated 10.14.2011, Figures L-10 and L-11 (Transect 4).

See Plate ES-2a for Transect 4 location.

0 20' 40' 80'
VERTICAL SCALE: 1" = 40'

0 40' 80' 160'
HORIZONTAL SCALE: 1" = 80'

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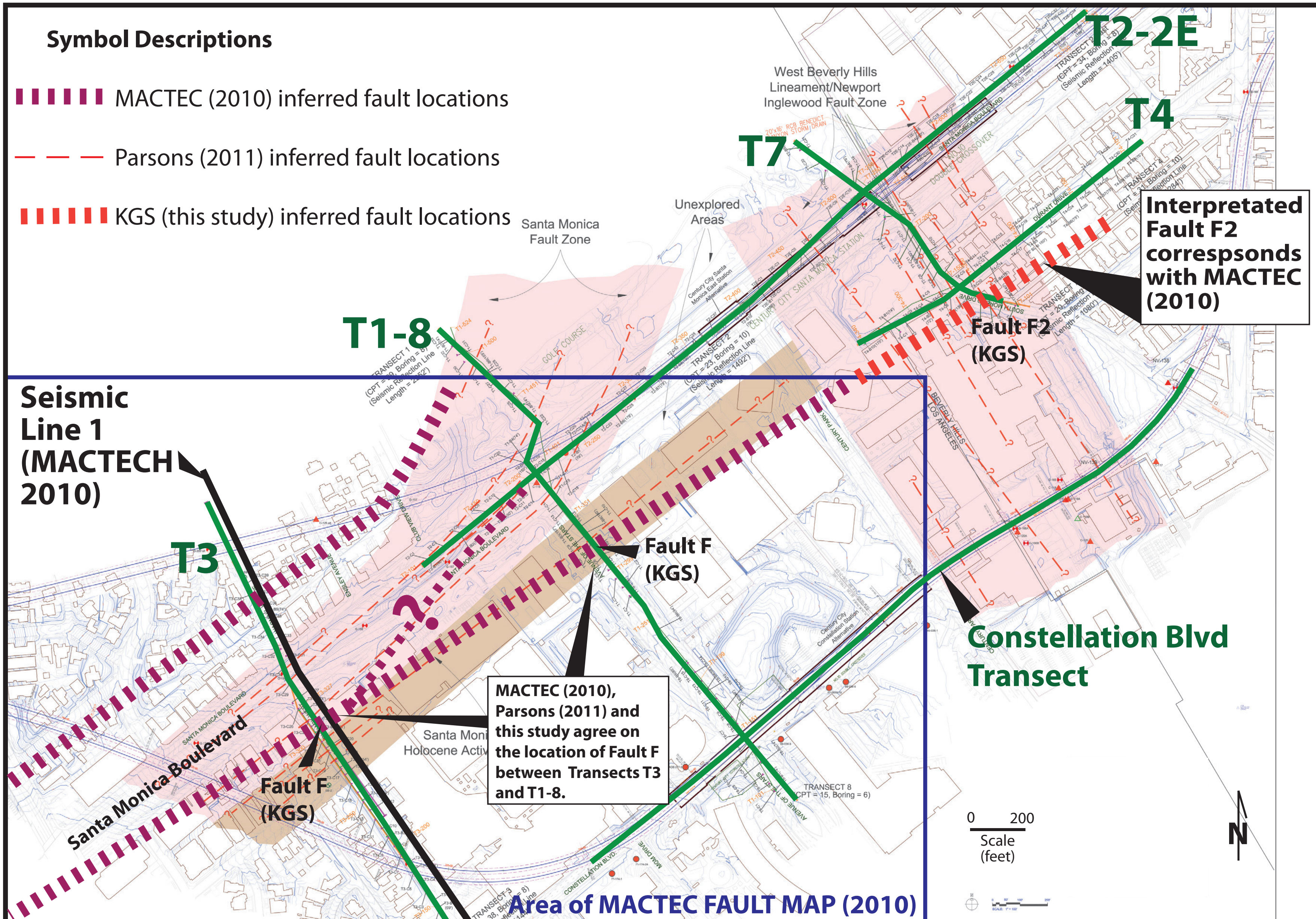
PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Transect 4 geologic cross-section

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-9



Base map: Parsons (2011)

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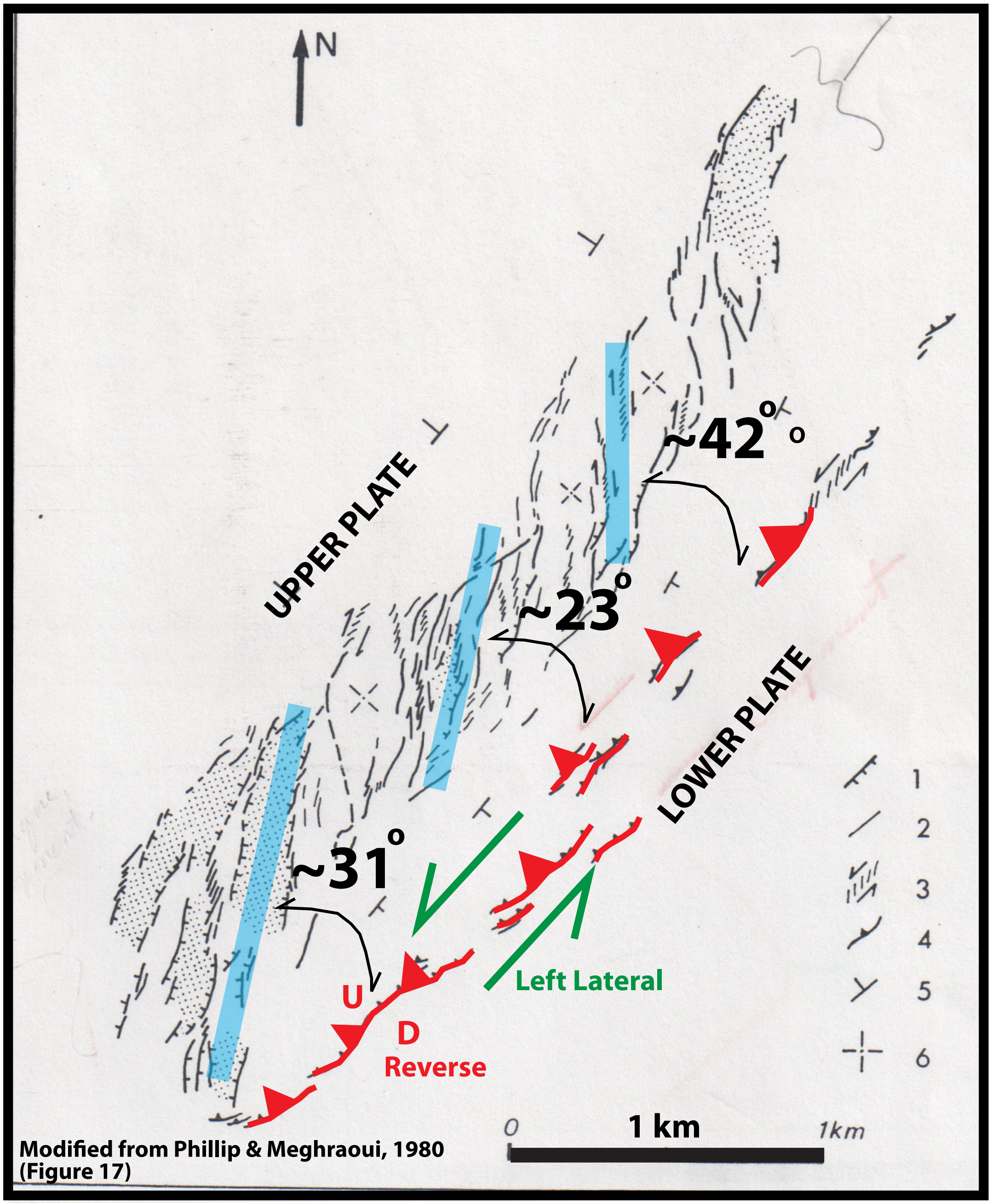
PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

MACTEC, Parsons & KGS fault map overlay - Faults F & F2

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-10



Historic surface-rupture evidence of a left-lateral reverse fault where secondary upper plate faults trend approximately 23 to 42 degrees (average 34 degrees) from the strike of the basal primary fault. Strike-slip motion on the upper plate secondary faults have primarily right-lateral normal displacement. Symbol legend: 1, normal faults; 2 tensile cracks; 3, en echelon cracks; 4, thrust faults and pressure ridges; 5, strike and dip of the bedding; 6, horizontal stratification.

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PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

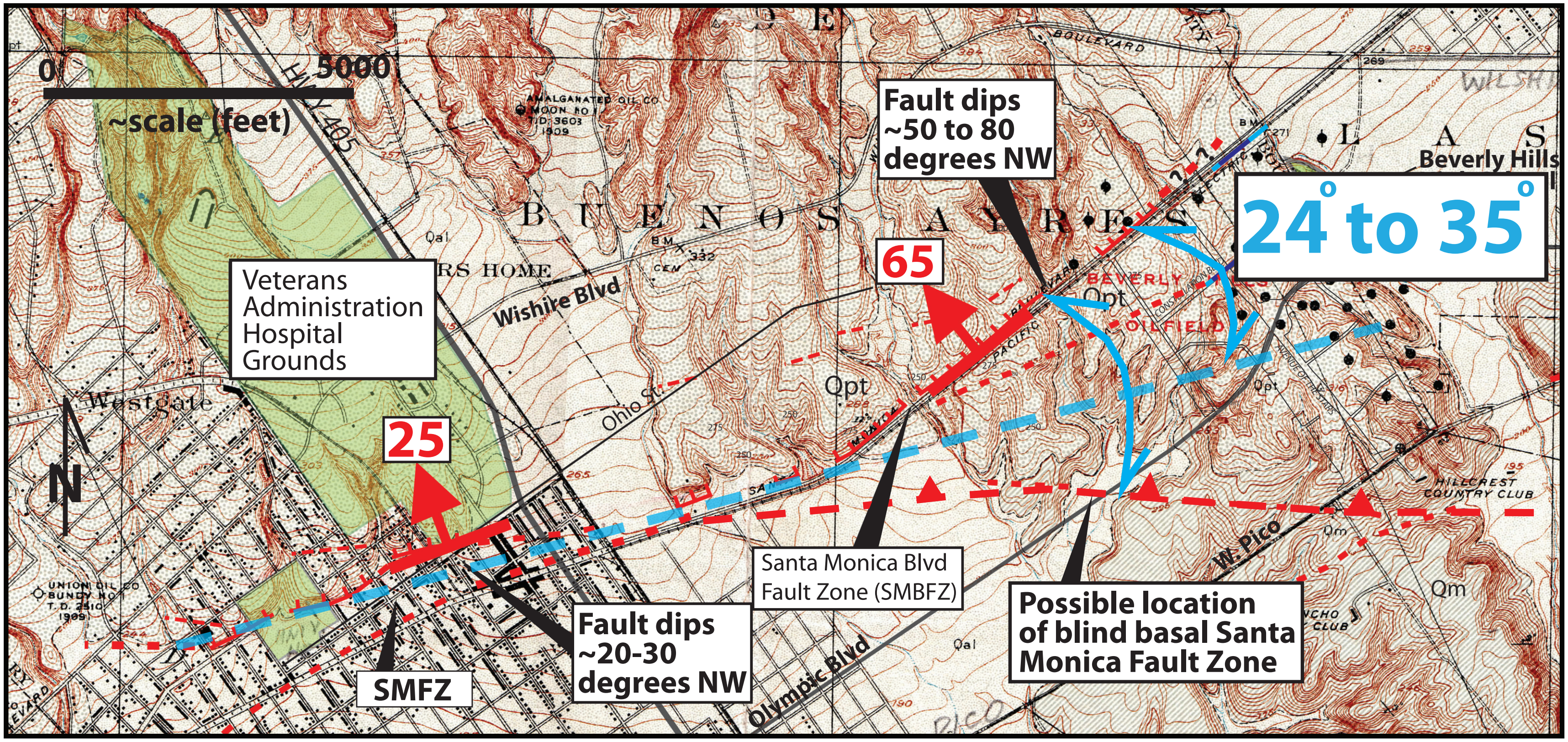
Average strike between secondary upper plate faults and the basal primary oblique reverse fault

Job No. 723-11

Date: JULY, 2012

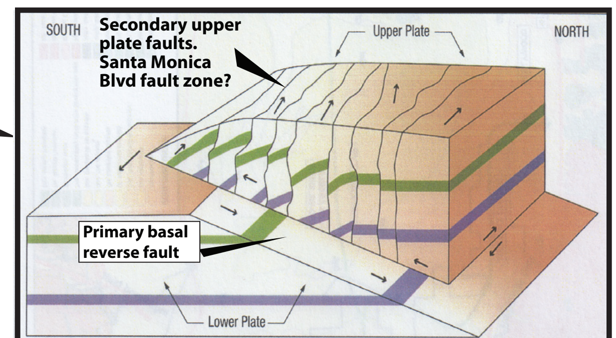
Drafted by: MK

PLATE ES-11



Base map from Hoots (1931).

Modified schematic block diagram of the Santa Monica Fault Zone, an oblique left-lateral reverse fault zone (from Parsons, 2011).



Schematic block diagram of the Santa Monica Fault Zone, an oblique left-lateral reverse fault zone.

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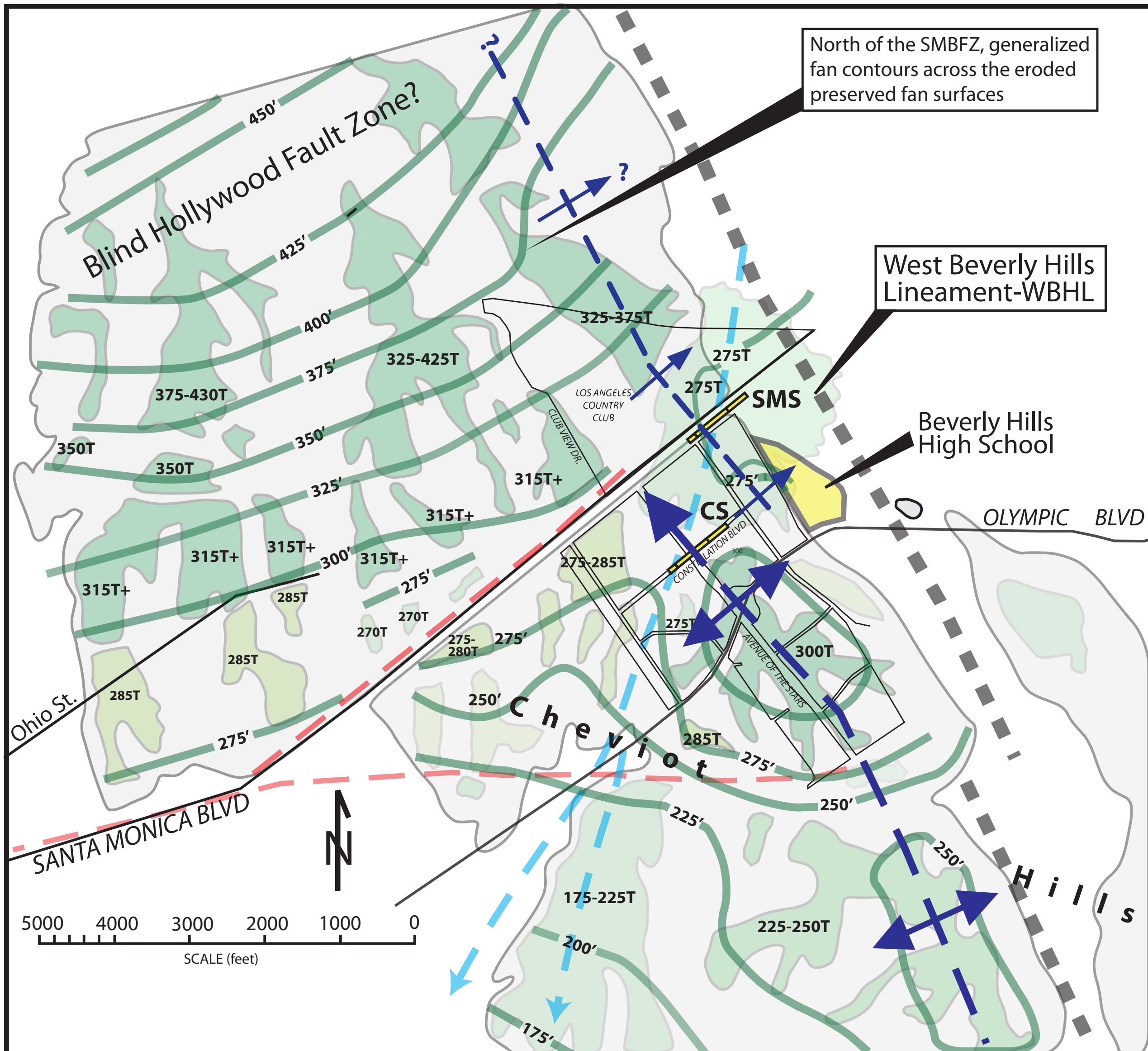
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

The location of the Santa Monica Fault Zone and the Santa Monica Blvd Fault Zone, Cheviot Hills area

Job No. 723-11
Date: JULY, 2012
Drafted by: MK

PLATE ES-12



SYMBOL DESCRIPTIONS

Approximate location of inferred fault zones (see text and for details)

ANTICLINE AND MONOCLINE:
Approximate location of anticline (upper symbol) and monocline fold axis within the San Pedro Sequence and Cheviot Hills Deposits (see text for details).

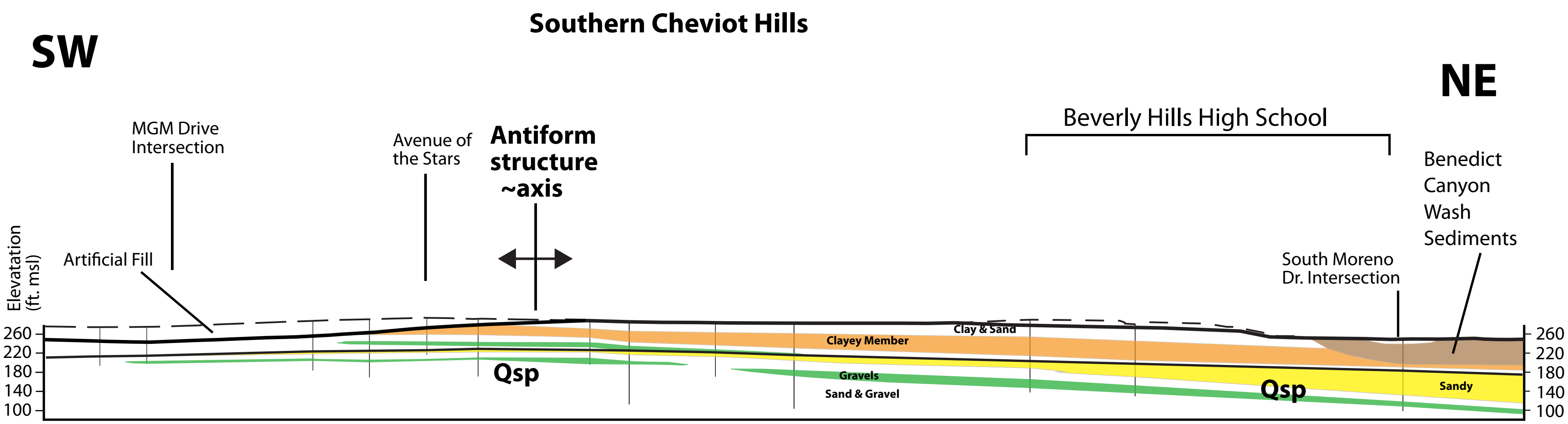
SMS / CS — Approximate location of proposed LA Metro substation.
SMS - Santa Monica Blvd Station;
CS - Constellation Blvd Station.

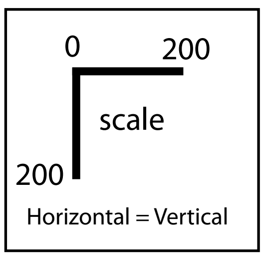
290T+ — Approximate limits of degraded remnant fan terrace surfaces (fill &/or cut terraces). Numbers are approximate average elevation of surface.

275' — Generalized elevations extropolated over fan-terrace surfaces. Bold number indicates approximate average elevation in feet.

Generalized location of proposed ancestrial Benedict Canyon Wash that flowed toward the southwest across and through the Cheviot Hills.

Kenney GeoScience	CLIENT: HILL, FARRER & BURRILL LLP PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	**Geomorphic terrace map of the Cheviot Hills showing showing surface folding**	Job No. 723-11 Date: JULY, 2012 Drafted by: MK **PLATE ES-13**



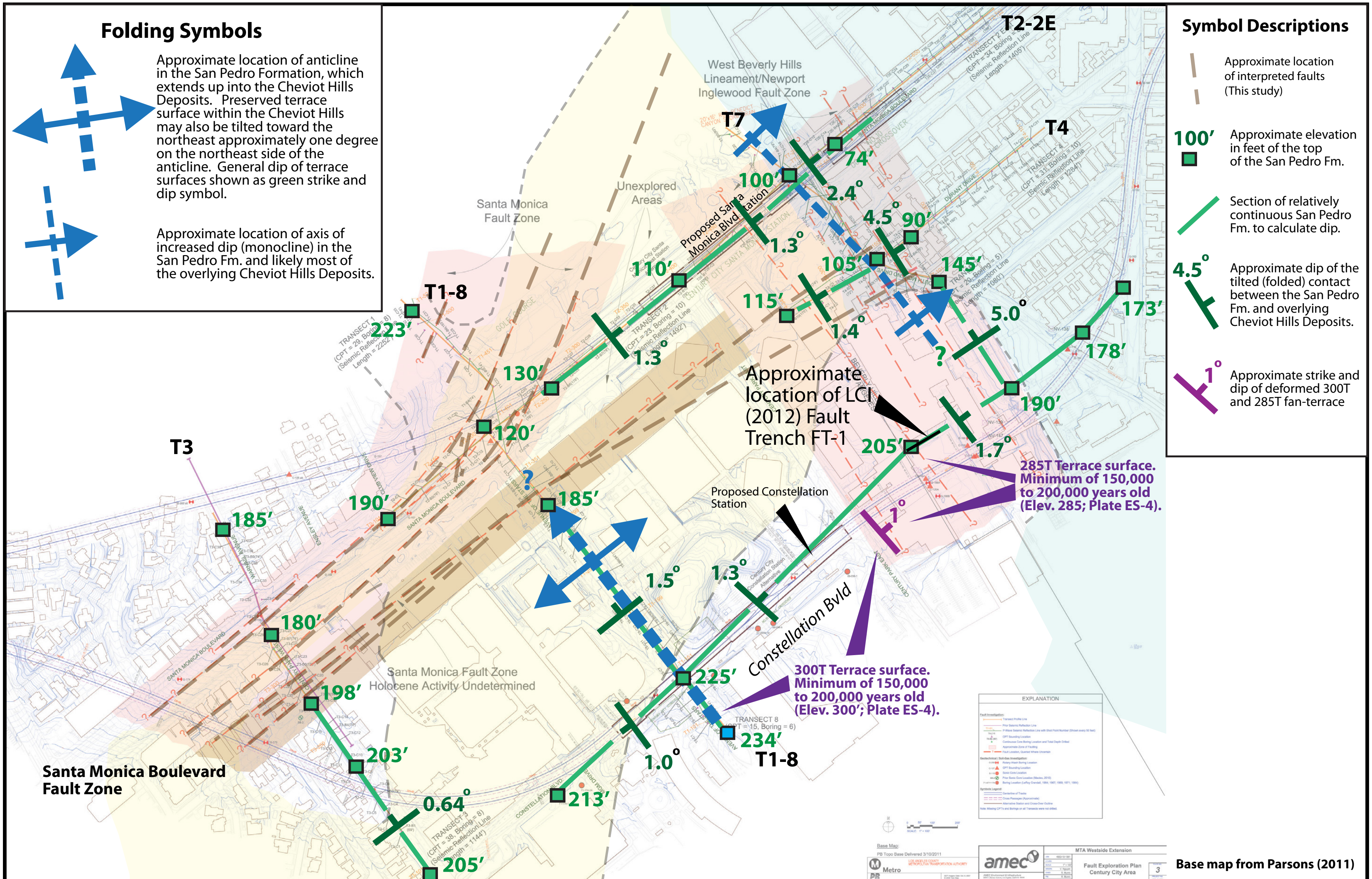


Gentle open fold in the San Pedro formation (Qsp) and overlying sediments (Cheviot Hills Deposits) within the southern Cheviot Hills. This anticline plunges towards the northward. The fold mimics the original surface of the Cheviot Hills.

Approximate antiform folding/uplift rate during the past 600,000 years is ~0.02 mm/year.

See Plate ES-2a for a map location of the Constellation Blvd cross section.

Kenney GeoScience	CLIENT: HILL, FARRER & BURRILL LLP PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	**Cross-section along Constellation Blvd showing true scale of near surface folding, Century City Area**	Job No. 723-11 Date: JULY, 2012 Drafted by: MK **PLATE ES-14**

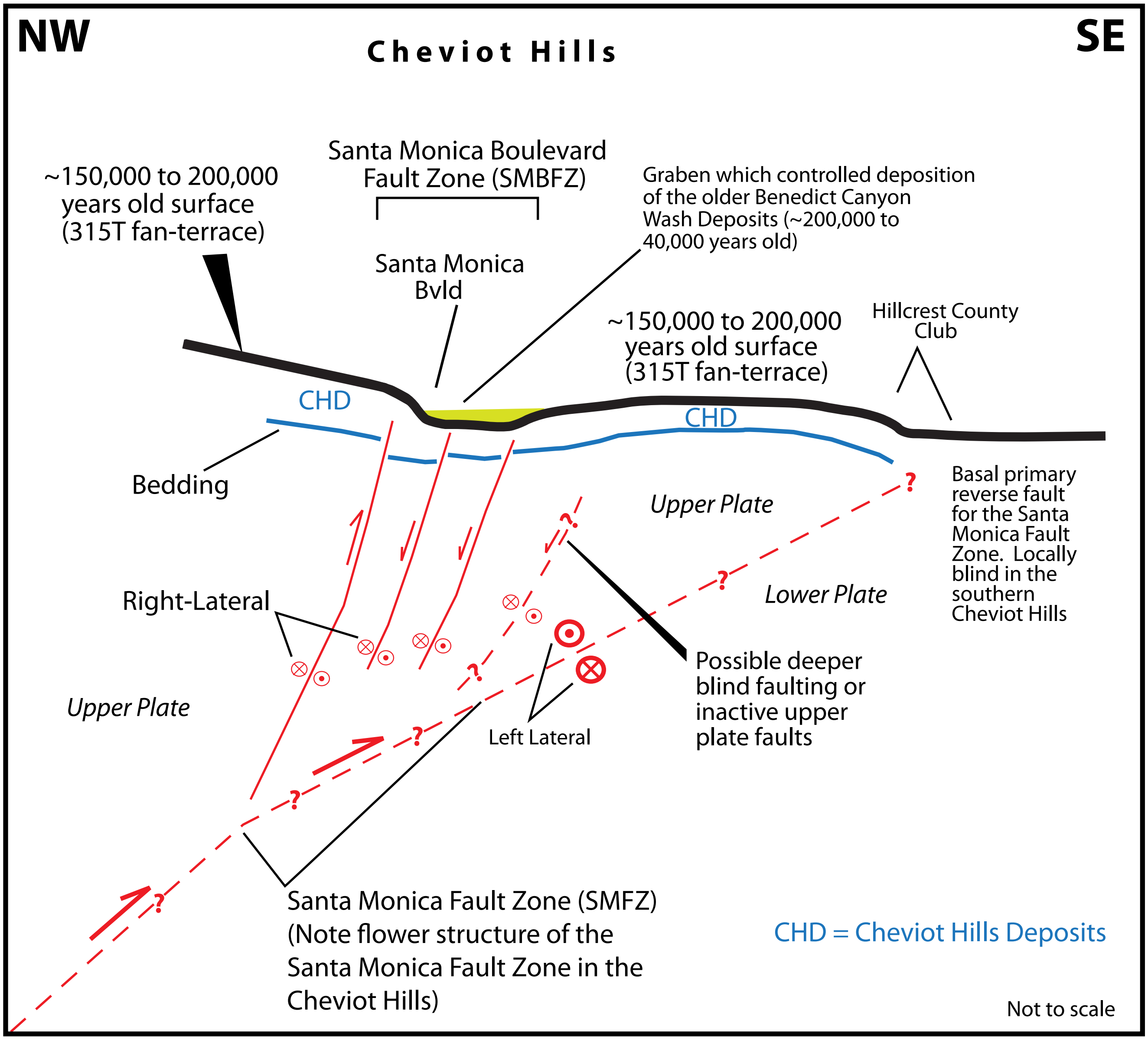


CLIENT: HILL, FARRER & BURRILL LLP	Job No. 723-11
PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	Date: JULY, 2012 Drafted by: MK

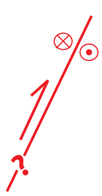
Folding data, Century City area

Kenney GeoScience

PLATE ES-15

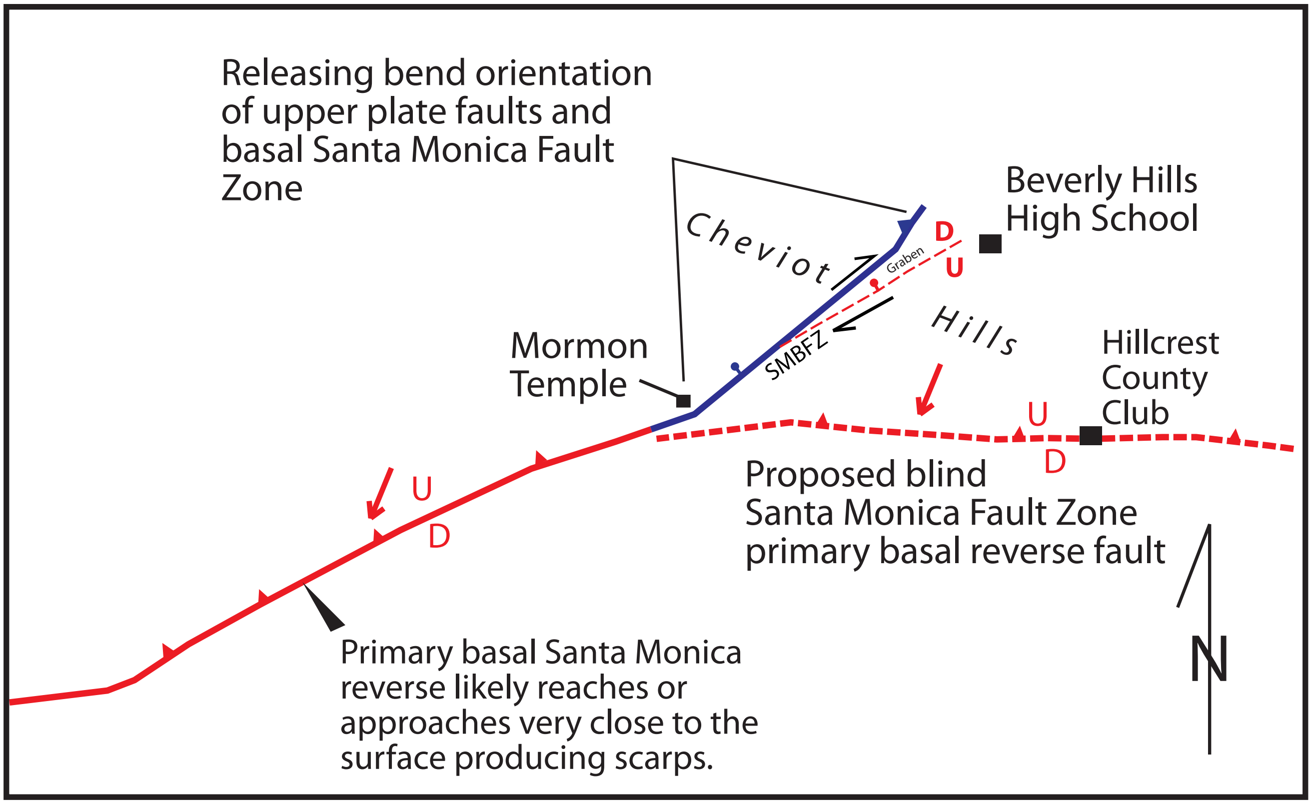


SYMBOL DESCRIPTIONS



Approximate location of fault.
Queried and dashed where uncertain.
Circle with cross and dot on either side
of fault infers rocks move away and
toward viewer respectively. Barb
half arrow infers fault motion direction
within the cross section.

Kenney GeoScience	CLIENT: HILL, FARRER & BURRILL LLP PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	**Diagrammatic Cross-section of the Santa Monica Fault Zone, Century City area**	Job No. 723-11 Date: JULY, 2012 Drafted by: MK **PLATE ES-16**



CLIENT:
HILL, FARRER & BURRILL LLP

PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

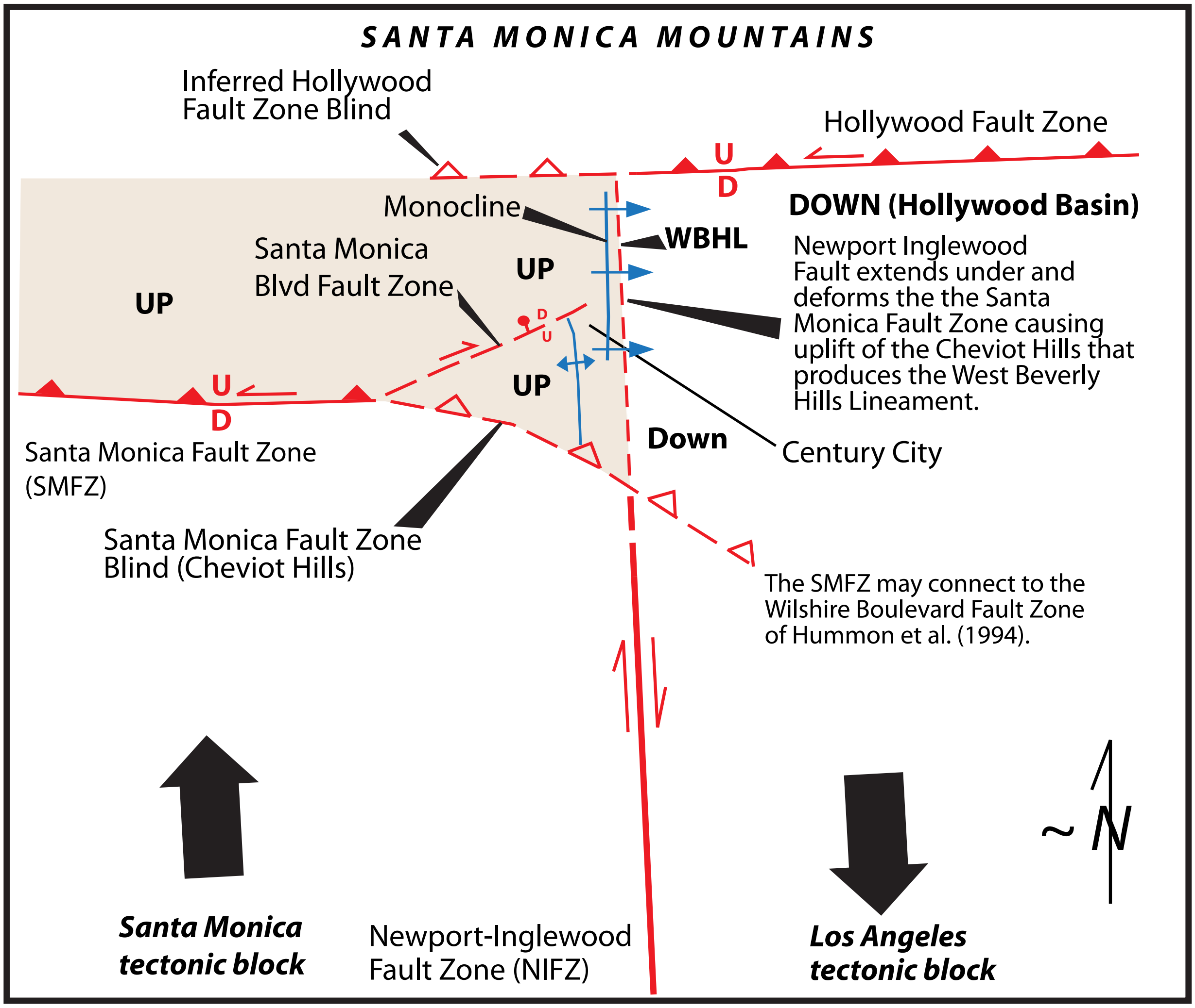
Kenney GeoScience

Releasing bend model in the Santa Monica Blvd Fault Zone, Century City area

Job No. 723-11

Date: JULY, 2012
Drafted by: MK

PLATE ES-17



Kenney GeoScience

CLIENT:
HILL, FARRER & BURRILL LLP

PROJECT:
GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA

Conceptual model of the interactions of the Santa Monica and Newport-Inglewood Fault Zones, Century City area

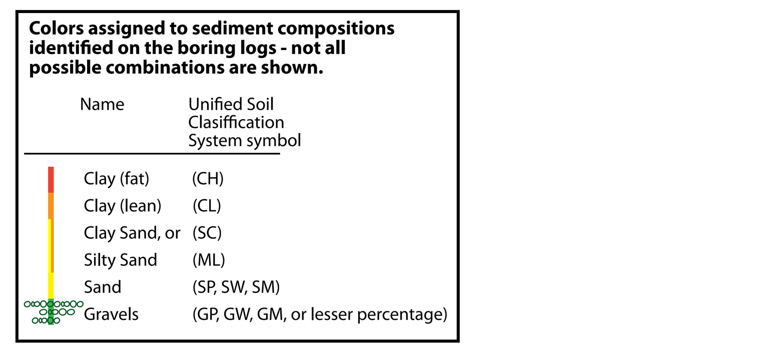
Job No. 723-11

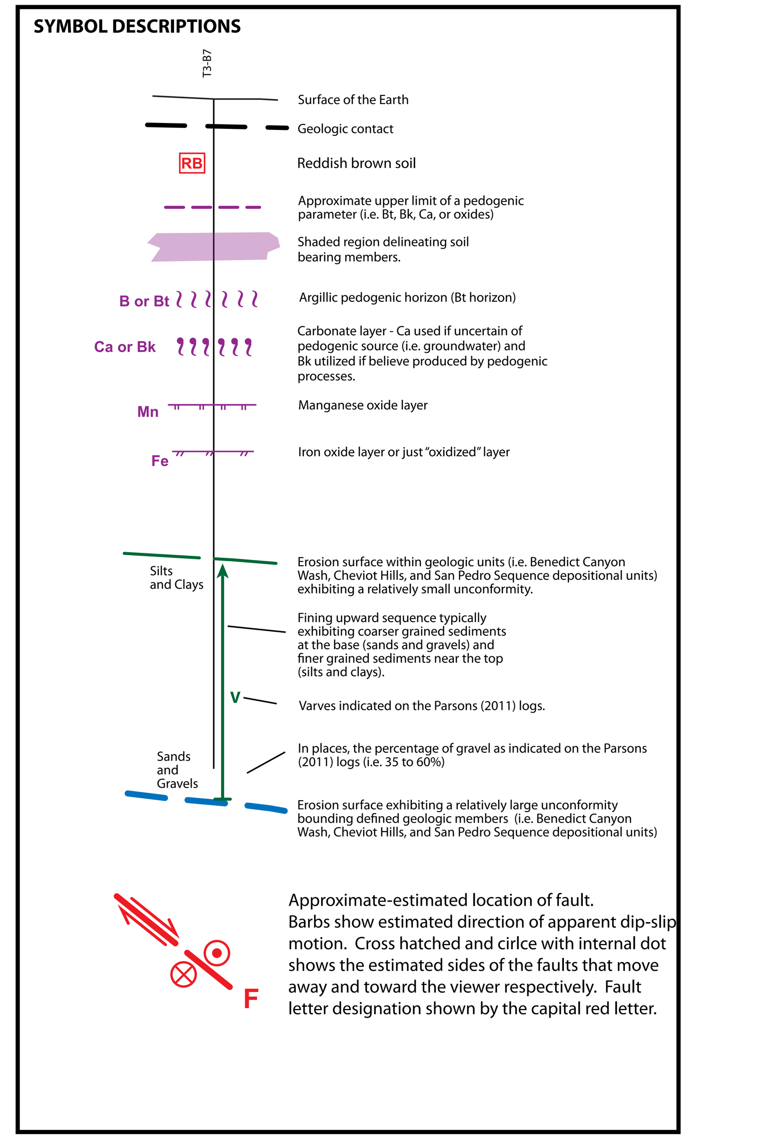
Date: JULY, 2012
Drafted by: MK

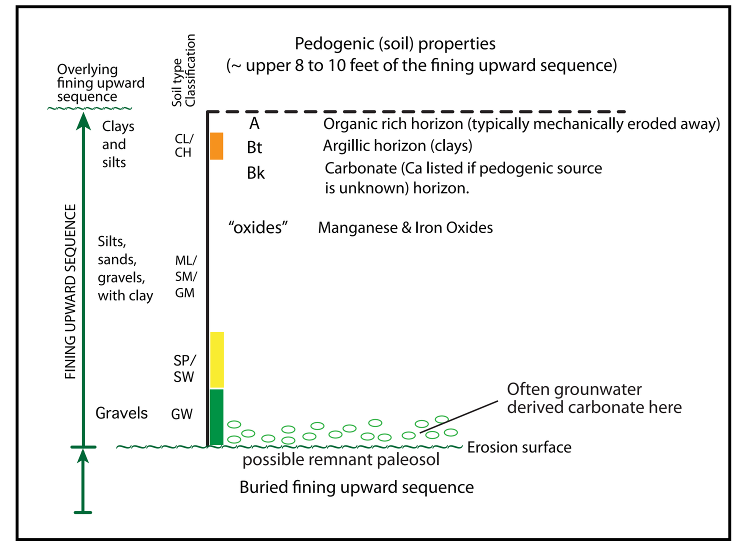
PLATE ES-18

Transect 1 & 8

EXPLANATION

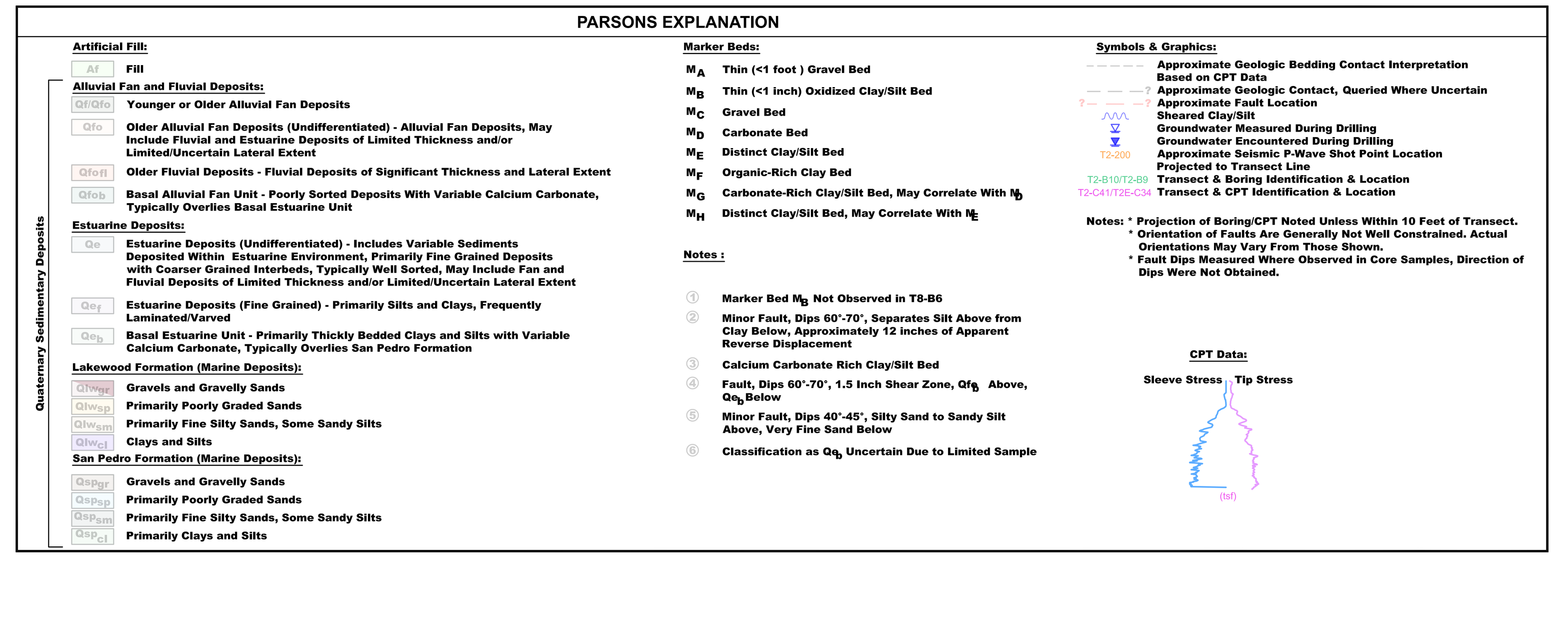






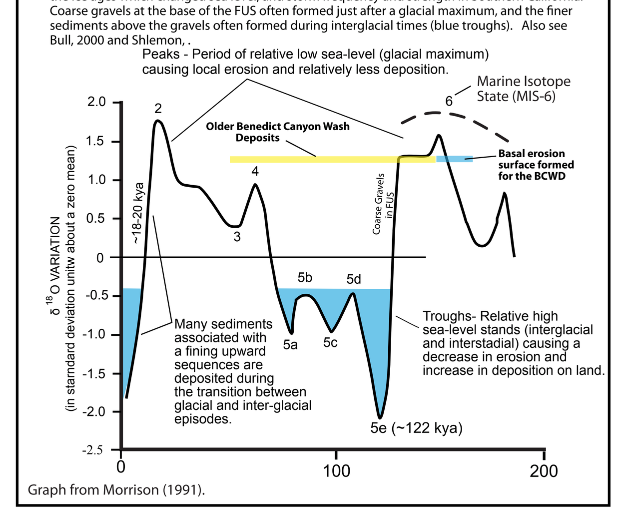
GEOLOGIC UNIT DESIGNATION			SYMBOL	DESCRIPTION	ESTIMATED AGE
			Af	Artificial fill	
Benedict Canyon Wash Deposits	BCWD	Younger BCWD	Qf/Qfo	Quaternary alluvium (late to latest Pleistocene) as defined by Parsons. Drawn in some areas where the original Parsons designation of Qf/Qfo was slightly modified herin. Unit Qf/Qfo likely includes uppermost members of ancient BCWDAT.	~40,000 years old (Soil Tectonics, 2012b). Terrace elevation approximately 275 to 280 msl
		Older BCWD	(A)	Soil profile marker horizon within Benedict Canyon Wash Deposits.	~134,000 years old (Soil Tectonics, 2012b)
					~150,000 years old erosion surface created during Marine Isotope Stage 6
			"300T" terrace surface	Abandoned geomorphic fan-terrace surfaces that locally ranges in elevation between approximately 285 to 350+ feet above msl (see Plate ES-4).	Minimum ~80,000 year old soil (Soil Tectonics, 2012a) but sediments may be as old as 150,000 to 200,000 years
Cheviot Hills Deposits	CHD		(B)	Soil profile marker horizon that typically exists in the uppermost section of the Cheviot Hills Deposits. Type local is in Boring T2E-B1. In most places the upper soil horizons have been eroded away.	~500,000 years old as correlated to dated soils in LCI (2012) and ECI (2012).
			(C)	Soil profile marker horizon with strong calcium carbonate. Type local identified in Boring T7-B2.	
			(D)	Soil profile marker horizon with distincive reddish brown color variations identified by Parsons (2011) as "spotted" and by LCI (personal communication) as "praprika", likely due to mottling. See Transect 7 (Plates KGS-7).	
					Erosion Surface
San Pedro Sequence	SPS		(E)	Soil profile marker horizon with manganese oxide and/or carbonate.	At LCI (2012) Boring CB-3, these soils likely do not exist due to erosion and thus were not dated
			(F)	Soil profile marker horizon with manganese oxide and/or carbonate. Typically overlies unit Qfob.	
			Qfob	Silty sand with clay and abundant carbonate. Identified by Parsons (2011)	Minimum ~574,000 years old as correlated to dated soils in LCI (2012) and ECI (2012).
			Qeb	Clay with abundant carbonate. Identified by Parsons (2011) and based on their data unit Qeb is likely comformable with the underlying San Pedro Formation. Unit is likely terrestrial.	
			Qsp	San Pedro Formation. Marine deposits with abundant shells and distinctive dark colors and well sorted clay, sand, and gravel layers.	Minumum 600,000 years old (LCI, 2012; ECI, 2012).

PARSONS EXPLANATION



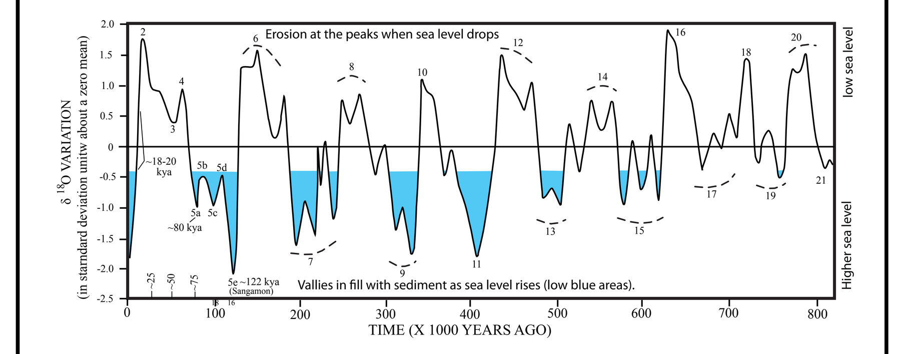
HOW FINING UPWARD SEQUENCES FORMED - AND THE BENEDICT CANYON WASH DEPOSITS

Many well defined fining upward sequences (FUS) formed due to variations of climate during the ice ages which changed sea level, and storm frequency and strength in Southern California. Coarse gravels at the base of the FUS often formed just after a glacial maximum, and the finer sediments above the gravels often formed during interglacial times (blue troughs). Also see Bull, 2000 and Shlemon, .



Graph from Morrison (1991).

GLACIALS AND INTERGLACIALS IN THE LATE PLEISTOCENE



Modified from Morrison (1991). Record of O/ O variations in five deep-sea cores, tuned to eadh other and to erth-orbital parameters, as a function of time, plotted from Table 7 data in Imbrie and others (1984) Color (blue) shows the interglacial episodes (high sea level), based on a cutoff at -0.5 δ O oxygen-isotope stages; the even-numbered peaks (at top) are glacial maxima (i.e relative low sea level stands), and odd-numbered troughs are interglacial minima (relative high sea level stands). Note: The portions of this graph older than 620 ka are here regarded as somewhat too young, and the portions older than 475 ka are believed to suppress excessively the oxygen-istope minima for interglacial stages 13 through 21 (modified from Morrison, 1991).

SCALE (VERTICAL = 2XHORIZONTAL)

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

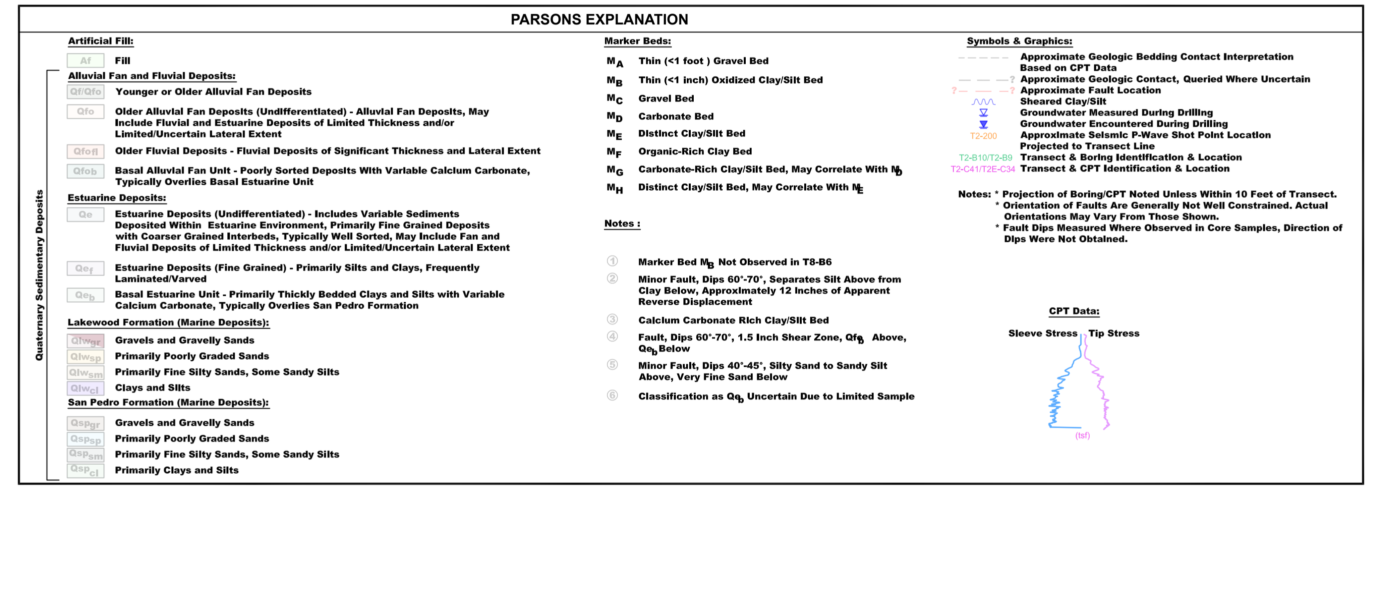
Kenney GeoScience	CLIENT: HILL, FARRER & BURRILL LLP PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	Modified CPT and Boring Cross Section of **Transects 1 & 8** of Parsons (2011), Century City Area, City of Los Angeles	Job No. 723-11 Date: JULY, 2012 Drafted by: DS, MK PLATE KGS-T1

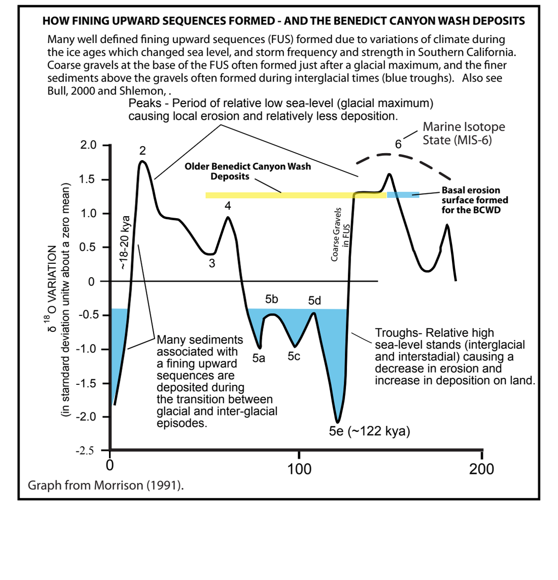
Transect 2 & 2 East

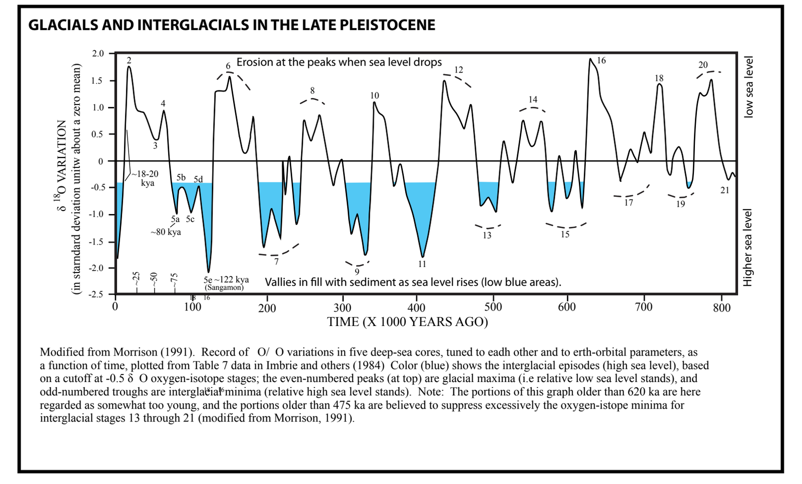
SANTA MONICA BOULEVARD FAULT ZONE
Identified faults in this study are similar in location as those identified by Parsons (2011). As shown here, Faults C, D2, E1 and E2 are likely inactive, and fault D1 reaches the closest to the surface. However sediments at the top of fault D1 are likely BCWD that range in age from 150 to 40 kya.

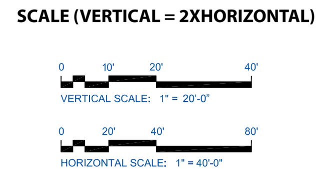
Notice the basin (graben) produced by faults D1, D2, E1 and E2. This depression is believed to have offset terrace 300T and allowed the ancient Benedict Canyon Wash to be captured and flow through the Cheviot Hills. Faulting continued during BCWD deposition.

GEOLOGIC UNIT DESIGNATION		SYMBOL	DESCRIPTION	ESTIMATED AGE
		Af	Artificial fill	
Benedict Canyon Wash Deposits (BCWD)	Younger BCWD	Qf/Qfo	Quaternary alluvium (late to latest Pleistocene) as defined by Parsons. Drawn in some areas where the original Parsons designation of Qf/Qfo was slightly modified herin. Unit Qf/Qfo likely includes uppermost members of ancient BCWDAT.	~40,000 years old (Soil Tectonics, 2012b). Terrace elevation approximately 275 to 280 msl
	Older BCWD	A	Soil profile marker horizon within Benedict Canyon Wash Deposits.	~134,000 years old (Soil Tectonics, 2012b)
				~150,000 years old erosion surface created during Marine Isotope Stage 6
		"300T" terrace surface	Abandoned geomorphic fan-terrace surfaces that locally ranges in elevation between approximately 285 to 350+ feet above msl (see Plate ES-4).	Minimum ~80,000 year old soil (Soil Tectonics, 2012a) but sediments may be as old as 150,000 to 200,000 years
Cheviot Hills Deposits (CHD)		B	Soil profile marker horizon that typically exists in the uppermost section of the Cheviot Hills Deposits. Type local is in Boring T2E-B1. In most places the upper soil horizons have been eroded away.	~500,000 years old as correlated to dated soils in LCI (2012) and ECI (2012).
		C	Soil profile marker horizon with strong calcium carbonate. Type local identified in Boring T7-B2.	
		D	Soil profile marker horizon with distincive reddish brown color variations identified by Parsons (2011) as "spotted" and by LCI (personal communication) as "praprika", likely due to mottling. See Transect 7 (Plates KGS-7).	
			Erosion Surface	
San Pedro Sequence (SPS)		E	Soil profile marker horizon with manganese oxide and/or carbonate.	At LCI (2012) Boring CB-3, these soils likely do not exist due to erosion and thus were not dated
		F	Soil profile marker horizon with manganese oxide and/or carbonate. Typically overlies unit Qfob.	
		Qfob	Silty sand with clay and abundant carbonate. Identified by Parsons (2011)	Minimum ~574,000 years old as correlated to dated soils in LCI (2012) and ECI (2012).
		Qeb	Clay with abundant carbonate. Identified by Parsons (2011) and based on their data unit Qeb is likely comformable with the underlying San Pedro Formation. Unit is likely terrestrial.	
		Qsp	San Pedro Formation. Marine deposits with abundant shells and distinctive dark colors and well sorted clay, sand, and gravel layers.	Minumum 600,000 years old (LCI, 2012; ECI, 2012).









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

Kenney GeoScience	CLIENT: HILL, FARRER & BURRILL LLP PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	Modified CPT and Boring Cross Section of **Transects 2 & 2E** of Parsons (2011), Century City Area, City of Los Angeles	Job No. 723-11 Date: JULY, 2012 Drafted by: DS, MK PLATE KGS-T2

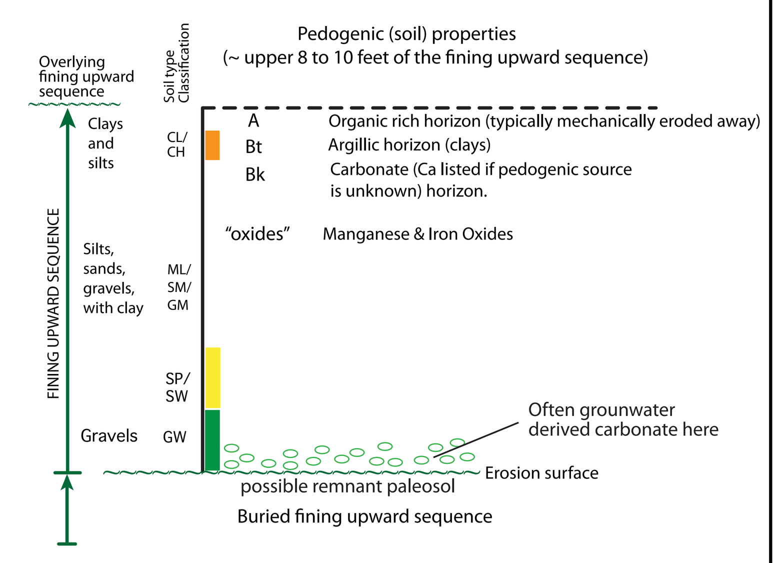
EXPLANATION

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

Name	Unified Soil Classification System symbol
Clay (fat)	(CH)
Clay (lean)	(CL)
Clay Sand, or	(SC)
Silty Sand	(ML)
Sand	(SP, SW, SM)
Gravels	(GP, GW, GM, or lesser percentage)

SYMBOL DESCRIPTIONS

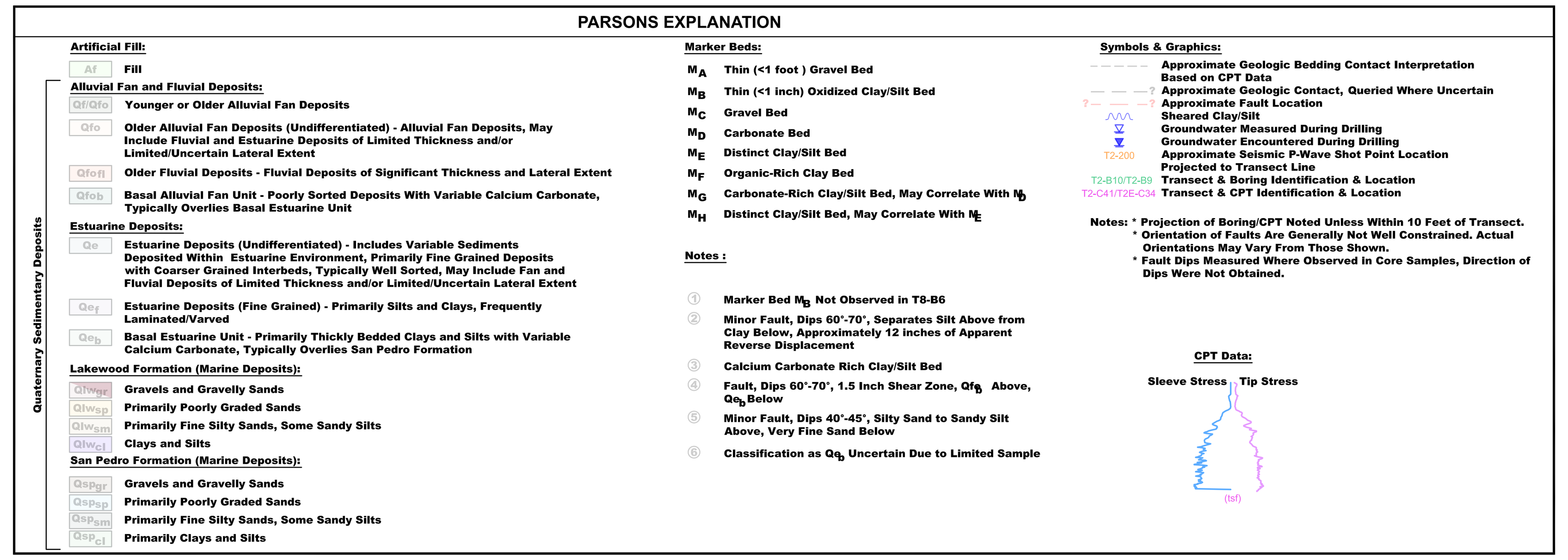
- Surface of the Earth
- Geologic contact
- RB — Reddish brown soil
- Approximate upper limit of a pedogenic parameter (i.e. Bt, Bk, Ca, or oxides)
- Shaded region delineating soil bearing members.
- B or Bt — Argillic pedogenic horizon (Bt horizon)
- Ca or Bk — Carbonate layer - Ca used if uncertain of pedogenic source (i.e. groundwater) and Bk utilized if believe produced by pedogenic processes.
- Mn — Manganese oxide layer
- Fe — Iron oxide layer or just "oxidized" layer
- Erosion surface within geologic units (i.e. Benedict Canyon Wash, Cheviot Hills, and San Pedro Sequence depositional units) exhibiting a relatively small unconformity.
- 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).
- V — Varves indicated on the Parsons (2011) logs.
- In places, the percentage of gravel as indicated on the Parsons (2011) logs (i.e. 35 to 60%)
- Erosion surface exhibiting a relatively large unconformity bounding defined geologic members (i.e. Benedict Canyon Wash, Cheviot Hills, and San Pedro Sequence depositional units)
- F — Approximate-estimated location of fault. Barbs show estimated direction of apparent dip-slip motion. Cross hatched and cirlce with internal dot shows the estimated sides of the faults that move away and toward the viewer respectively. Fault letter designation shown by the capital red letter.



Transect 4

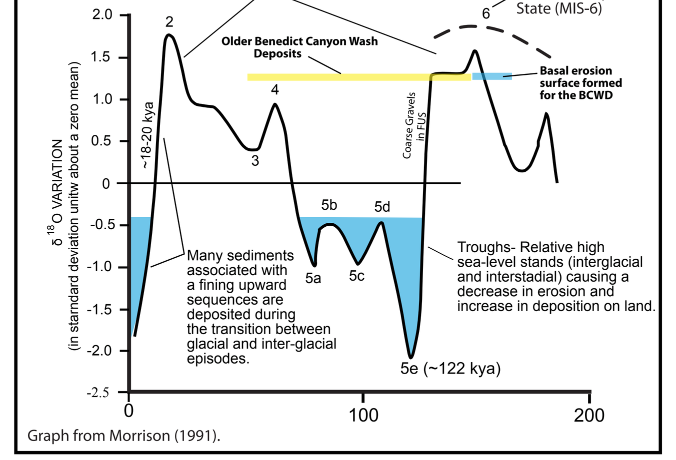
GEOLOGIC UNIT DESIGNATION		SYMBOL	DESCRIPTION	ESTIMATED AGE
		Af	Artificial fill	
Benedict Canyon Wash Deposits (BCWD)	Younger BCWD	Qf/Qfo	Quaternary alluvium (late to latest Pleistocene) as defined by Parsons. Drawn in some areas where the original Parsons designation of Qf/Qfo was slightly modified herin. Unit Qf/Qfo likely includes uppermost members of ancient BCWDAT.	~40,000 years old (Soil Tectonics, 2012b). Terrace elevation approximately 275 to 280 msl
	Older BCWD	A	Soil profile marker horizon within Benedict Canyon Wash Deposits.	~134,000 years old (Soil Tectonics, 2012b)
				~150,000 years old erosion surface created during Marine Isotope Stage 6
Cheviot Hills Deposits (CHD)		"300T" terrace surface	Abandoned geomorphic fan-terrace surfaces that locally ranges in elevation between approximately 285 to 350+ feet above msl (see Plate ES-4).	Minimum ~80,000 year old soil (Soil Tectonics, 2012a) but sediments may be as old as 150,000 to 200,000 years
		B	Soil profile marker horizon that typically exists in the uppermost section of the Cheviot Hills Deposits. Type local is in Boring T2E-B1. In most places the upper soil horizons have been eroded away.	~500,000 years old as correlated to dated soils in LCI (2012) and ECI (2012).
		C	Soil profile marker horizon with strong calcium carbonate. Type local identified in Boring T7-B2.	
		D	Soil profile marker horizon with distincive reddish brown color variations identified by Parsons (2011) as "spotted" and by LCI (personal communication) as "praprika", likely due to mottling. See Transect 7 (Plates KGS-7).	
			Erosion Surface	
San Pedro Sequence (SPS)		E	Soil profile marker horizon with manganese oxide and/or carbonate.	At LCI (2012) Boring CB-3, these soils likely do not exist due to erosion and thus were not dated
		F	Soil profile marker horizon with manganese oxide and/or carbonate. Typically overlies unit Qfob.	
		Qfob	Silty sand with clay and abundant carbonate. Identified by Parsons (2011)	Minimum ~574,000 years old as correlated to dated soils in LCI (2012) and ECI (2012).
		Qeb	Clay with abundant carbonate. Identified by Parsons (2011) and based on their data unit Qeb is likely comformable with the underlying San Pedro Formation. Unit is likely terrestrial.	
		Qsp	San Pedro Formation. Marine deposits with abundant shells and distinctive dark colors and well sorted clay, sand, and gravel layers.	Minumum 600,000 years old (LCI, 2012; ECI, 2012).

PARSONS EXPLANATION



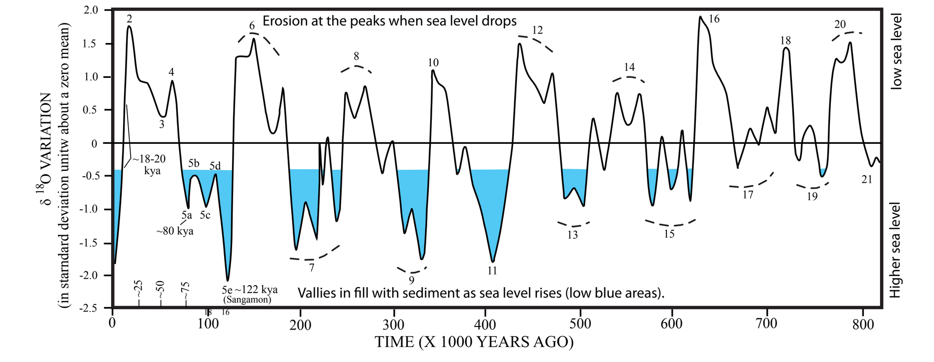
HOW FINING UPWARD SEQUENCES FORMED - AND THE BENEDICT CANYON WASH DEPOSITS

Many well defined fining upward sequences (FUS) formed due to variations of climate during the ice ages which changed sea level, and storm frequency and strength in Southern California. Coarse gravels at the base of the FUS often formed just after a glacial maximum, and the finer sediments above the gravels often formed during interglacial times (blue troughs). Also see Bull, 2000 and Shlemon, .



Graph from Morrison (1991).

GLACIALS AND INTERGLACIALS IN THE LATE PLEISTOCENE



Modified from Morrison (1991). Record of O/ O variations in five deep-sea cores, tuned to eadh other and to erth-orbital parameters, as a function of time, plotted from Table 7 data in Imbrie and others (1984) Color (blue) shows the interglacial episodes (high sea level), based on a cutoff at -0.5 δ O oxygen-isotope stages; the even-numbered peaks (at top) are glacial maxima (i.e relative low sea level stands), and odd-numbered troughs are interglacial minima (relative high sea level stands). Note: The portions of this graph older than 620 ka are here regarded as somewhat too young, and the portions older than 475 ka are believed to suppress excessively the oxygen-istope minima for interglacial stages 13 through 21 (modified from Morrison, 1991).

Scale (Vertical =2X Horizontal)

VERTICAL SCALE: 1" = 20'-0"

HORIZONTAL SCALE: 1" = 40'-0"

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

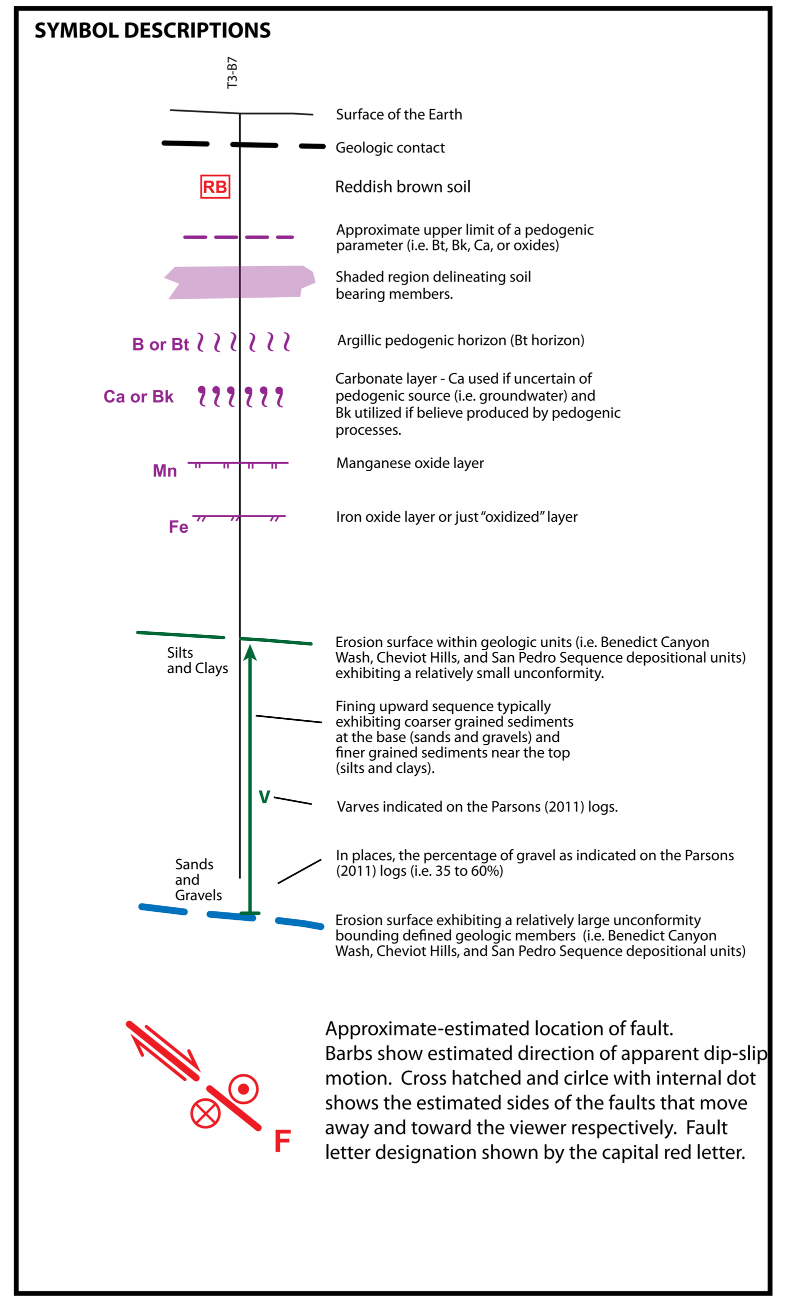
Kenney GeoScience — CLIENT: HILL, FARRER & BURRILL LLP; PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	Modified CPT and Boring Cross Section of **Transect 4** of Parsons (2011), Century City Area, City of Los Angeles	Job No. 723-11; Date: JULY, 2012; Drafted by: DS, MK; PLATE KGS-T4

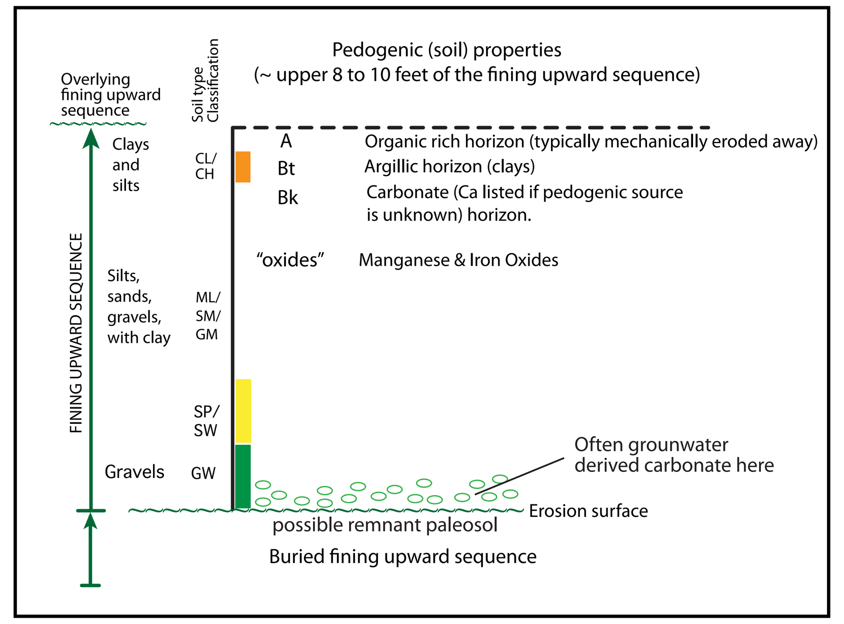
Transect 7

EXPLANATION

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

Name	Unified Soil Classification System symbol
Clay (fat)	(CH)
Clay (lean)	(CL)
Clay Sand, or Silty Sand	(SC) (ML)
Sand	(SP, SW, SM)
Gravels	(GP, GW, GM, or lesser percentage)





One of the steepest dips associated with top of the San Pedro Formation is identified between borings CB-7 (LCI, 2012) and T7-B1 (Parsons, 2011). The dip is approximately 4 to 5 degrees. Local folding is known to exist in the area (see report for details), relatively deep faults identified on the seismic refraction data (Parsons, 2011) and a "knob) in the subsurface structure contour map of the upper San Pedro Formation surface (Parsons, 2012) also suggest the possibility of a fault in this area.

GEOLOGIC UNIT DESIGNATION		SYMBOL	DESCRIPTION	ESTIMATED AGE
		Af	Artificial fill	
Benedict Canyon Wash Deposits BCWD	Younger BCWD	Qf/Qfo	Quaternary alluvium (late to latest Pleistocene) as defined by Parsons. Drawn in some areas where the original Parsons designation of Qf/Qfo was slightly modified herin. Unit Qf/Qfo likely includes uppermost members of ancient BCWDAT.	~40,000 years old (Soil Tectonics, 2012b). Terrace elevation approximately 275 to 280 msl
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Cheviot Hills Deposits CHD		"300T" terrace surface	Abandoned geomorphic fan-terrace surfaces that locally ranges in elevation between approximately 285 to 350+ feet above msl (see Plate ES-4).	Minimum ~80,000 year old soil (Soil Tectonics, 2012a) but sediments may be as old as 150,000 to 200,000 years
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				Erosion Surface
San Pedro Sequence SPS		E	Soil profile marker horizon with manganese oxide and/or carbonate.	At LCI (2012) Boring CB-3, these soils likely do not exist due to erosion and thus were not dated
		F	Soil profile marker horizon with manganese oxide and/or carbonate. Typically overlies unit Qfob.	
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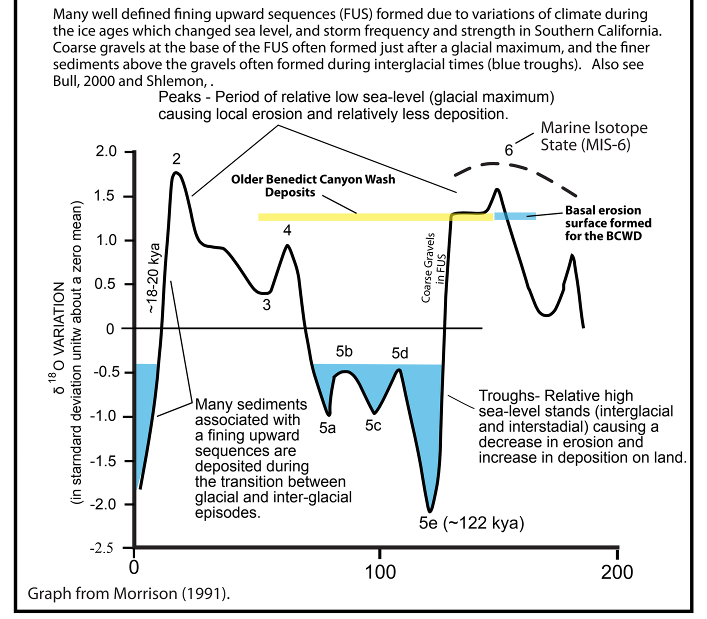
		Qsp	San Pedro Formation. Marine deposits with abundant shells and distinctive dark colors and well sorted clay, sand, and gravel layers.	Minumum 600,000 years old (LCI, 2012; ECI, 2012).

HOW FINING UPWARD SEQUENCES FORMED - AND THE BENEDICT CANYON WASH DEPOSITS

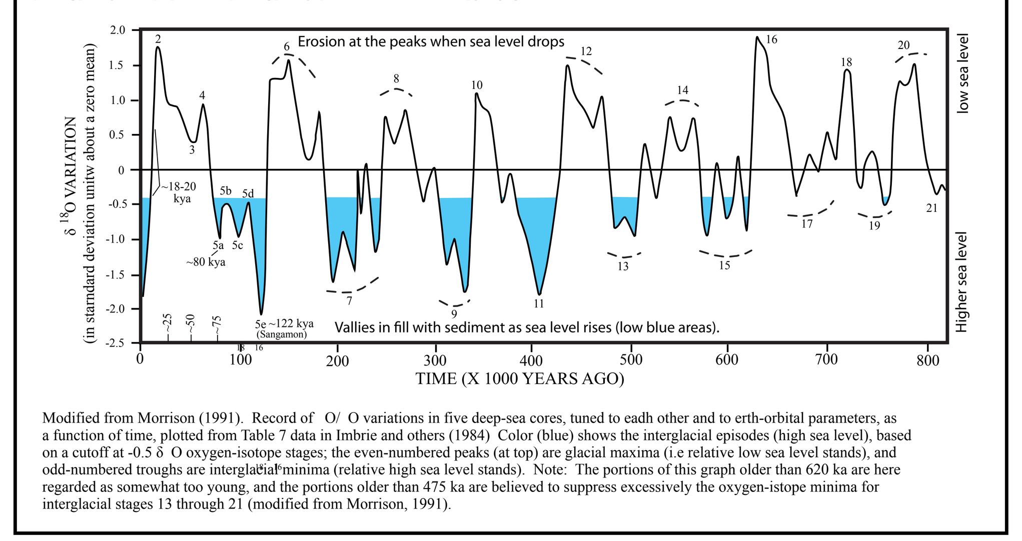


Graph from Morrison (1991).

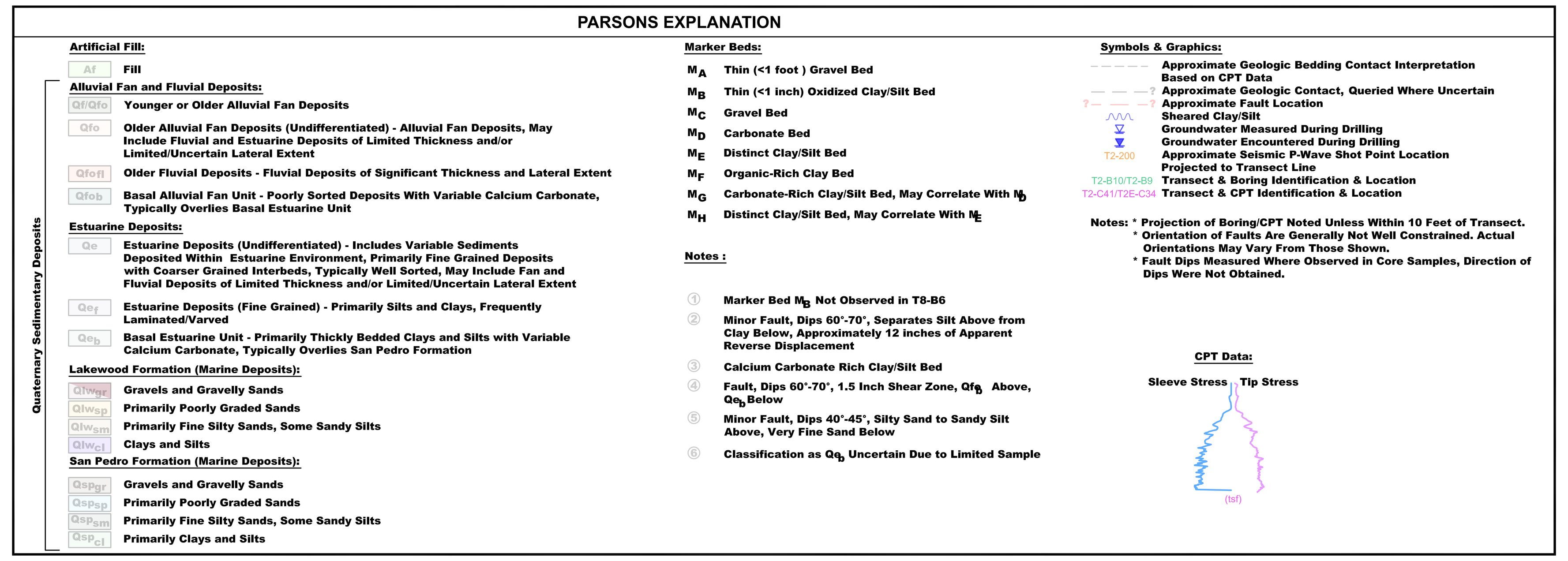
Santa Monica Boulevard Fault Zone

These faults are interpreted as striking northeast and are part of the Santa Monica Boulevard Fault Zone and not associated with the northwest trending WBHL-NIFZ of Parsons (2011). Faults F1 and F2 are likely not active as they do not appear to offset soil profiles (marker horizons) that are over 134,000 years old.

GLACIALS AND INTERGLACIALS IN THE LATE PLEISTOCENE



PARSONS EXPLANATION



Scale (Vertical = 2x Horizontal)

VERTICAL SCALE: 1" = 20'-0"

HORIZONTAL SCALE: 1" = 40'-0"

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

Kenney GeoScience	CLIENT: HILL, FARRER & BURRILL LLP PROJECT: GEOLOGIC EVALUATION OF THE SANTA MONICA FAULT ZONE IN THE CENTURY CITY AREA	Modified CPT and Boring Cross Section of **Transect 7** of Parsons (2011), Century City Area, City of Los Angeles	Job No. 723-11 Date: JULY, 2012 Drafted by: DS, MK PLATE KGS-T7