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Title: Direct mega-trench exposure of the buried fold scarp from the most recent Compton Thrust earthquake: Implications for surface deformation and seismic hazard

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Abstract

The goal of this project was to document the detailed geometry (width, height, and dip) of the fold scarp developed during the most recent earthquake on the blind Compton Thrust fault beneath the Los Angeles Basin. Such data are of critical importance for understanding the underappreciated surface deformation hazards posed to the metropolitan Los Angeles region by blind thrusts in general, and by the Compton thrust fault in particular. Following extensive reconnaissance as part of an earlier phase of this project, we selected two study sites where the zone of active faulting, as interpreted from petroleum industry seismic reflection data, reached the surface in areas where there was sufficient space to excavate a deep “mega-trench” that would reveal the detailed geometry of the now-buried fold scarp. Our preferred study site was located above the northern part of the Compton Thrust in a Los Angeles County park (Colonel Leon H. Washington Park) in the unincorporated Florence-Graham neighborhood 10 km south of downtown Los Angeles, whereas the second potential study site was located above the central part of the Compton Thrust on property owned by the California Department of Transportation (Caltrans) adjacent to the Los Angeles River 17 km SSE of downtown LA. After a year-long permitting process for the Florence-Graham site, we were allowed as part of this earlier effort to excavate several continuously cored hollow-stem boreholes at the inferred surface trace of the locus of recent folding above the Compton Thrust. These data revealed the anticlinal axial surface for the fold formed during the Compton Thrust MRE as well as the southern portion of the fold scarp. However, the borehole transect stopped short of the northern edge of the fold scarp and active synclinal axial surface. After requesting permission from LA County to extend our borehole transect further North in an effort to document the northern extent of the buried fold scarp (necessary for situating the proposed mega-trench) and going through an additional lengthy permitting process, we were surprisingly denied permission by LA County, as the County decided that there was no “public benefit” to the proposed research. After requesting a review of this decision and meeting with County personnel to explain that the project was aimed entirely for the benefit of the public, we were told that the case would be reviewed and they would contact us. They never contacted us and repeated email and voice mail requests for status updates were never returned. Faced with this intransigence on the part of LA County personnel, we turned our attention to the alternative southern study site owned by the California Department of Transportation. Caltrans personnel were extremely helpful during the lengthy permitting process. With permission in hand, we drilled a North-South transect of four continuously cored hollow-stem boreholes across the locus of active surface folding inferred from analysis of the seismic refection data. Unfortunately, these data revealed apparently flat-lying stratigraphy down to a depth of at least 10 m, and likely to the full 15 m depth of the boreholes. Thus, any record of folding at the site lies deeper than the depth of any potential trenching efforts. Following this second disappointment, we conducted a second comprehensive reconnaissance, both in the field and using satellite data, of potential sites along the surface traces of recent folding above not only the Compton Thrust, but the Puente Hills Thrust, as well. Unfortunately, we were unable to locate any other sites where there was sufficient land to excavate our proposed mega-trench.

Rationale for Proposed Research

The recent occurrence of several highly destructive earthquakes on thrust faults (e.g., 1994 M_w 6.7 Northridge, 1999 M_w 7.6 Chi-Chi, 2005 M_w 7.5 Kashmir, 2008 M_w 7.9 Wenchuan), and the growing recognition of the hazards posed by such structures to urban centers around the world, highlight the need to better understand the relationship between seismic slip on these faults and the resulting growth of folds. In the case of blind-thrust faults, in which thrust slip at depth is manifested in the near-surface as folding, surface fold scarps generated by large-magnitude earthquakes represent a potentially significant, yet underappreciated ground deformation hazard.

Folds develop in response to displacements on blind-thrust faults. On geologic time scales, these fault-related folds generally develop along the tips of propagating faults or above fault bends (e.g., *Suppe, 1983; Suppe and Medwedeff, 1990; Erslev, 1991; Shaw and Suppe, 1994; Allmendinger, 1998; Shaw et al., 2005*). Geodetic studies of several small- to moderate-magnitude blind-thrust earthquakes generally show a broad pattern of uplift centered above the fault rupture suggestive of a component of distributed folding (e.g., *Lin and Stein, 1989; Stein and Ekstrom, 1992*). Discrete fold scarps, however, have developed in response to large thrust earthquakes, such as during the 1980 M_w 7.3 El Asnam, Algeria, and 1999 M_w 7.6 Chi-Chi, Taiwan, events (*King and Vita-Finzi, 1981; Suppe et al., 2000*). These large-magnitude earthquakes involved ruptures that extended to fault tip lines, and across bends and along-strike segments of the thrust ramps. The Chi-Chi, Taiwan earthquake, in particular, demonstrates that a component of this localized folding occurs co-seismically. During the Chi-Chi event, destructive, co-seismic folding generated a 20-m-wide, 5-m-high, and more than 20-km-long fold scarp along a previously mapped geologic syncline that occurred above a bend in the Chenglupu fault (Figure 1) (*Suppe et al., 2000*).

Numerous studies have documented similar zones of discrete, near-surface folding above fault bends above a number of different blind thrust faults, including the Compton and Puente Hills blind thrust faults, the two largest such faults beneath metropolitan Los Angeles, California (Figure 2) (e.g., *Schneider et al., 1996; Mueller, 1998; Shaw and Shearer, 1999; Baldwin et al., 2000; Pratt et al., 2002; Shaw et al., 2002; Dolan et al., 2003; Leon et al., 2007; 2009; Hubbard et al., 2014; McAuliffe et al., 2015*). Yet the details of this potentially significant surface deformation hazard remain incompletely understood. For example, as described in detail below, in our previous documentation of now-buried fold scarps formed in ancient blind thrust earthquakes beneath Los Angeles, the wide spacing of our borehole observations precludes precise measurement of the width of the zone of folding; in even our best-constrained examples, the potential width of the zone of folding associated with the most recent earthquake could vary from as little as 40 m to as much as 120 m (*Leon et al., 2009*). To move forward in our understanding of blind-thrust surface deformation hazards, we need to make much more detailed observations of the folding that has occurred in previous large-magnitude earthquakes. Specifically, we need to document the detailed geometry, width, height, and dip of surface in a variety of sedimentary environments in order to provide governmental regulatory agencies with the data necessary to begin to make informed decisions about both hazard assessment and mitigation strategies for this poorly understood surface deformation hazard.

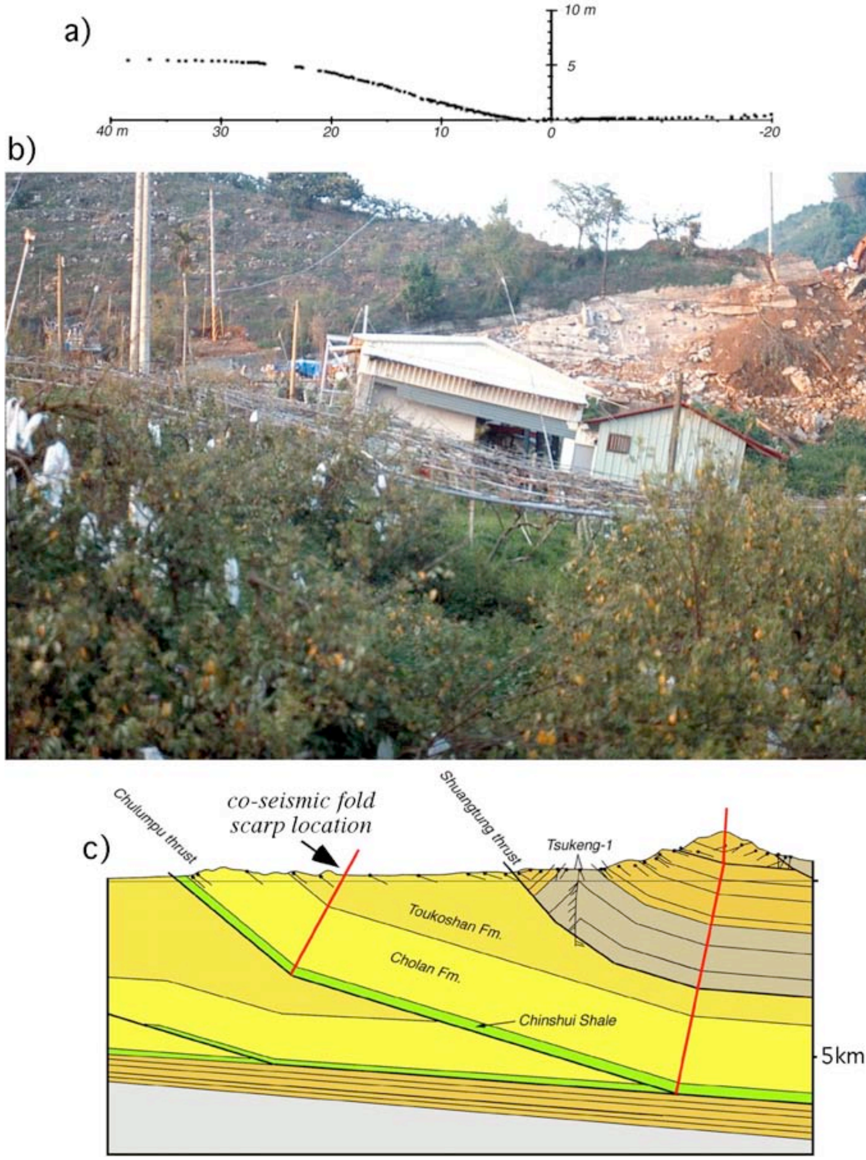

Figure 1. Topographic survey (a) and photo (b) of the fold scarp in Neiwan that developed during the 1999 Chi-Chi (Mw 7.6), Taiwan earthquake. The fold scarp extended for several tens of kilometers along strike, and formed along a mapped geologic syncline that developed above a bend in the Chenglupu thrust, as shown in the cross section (c). After Suppe et al. (2000).

Nowhere are blind thrust faults of more concern than beneath the Los Angeles metropolitan region, one of the world's great commercial centers and home to more than 13 million people. Previous studies have identified several major blind thrust faults beneath the city, with two – the Compton and Puente Hills faults – being of particular concern because of their location directly beneath the urban center (Figure 2) (*Shaw and Suppe*, 1996; *Shaw et al.,* 2002).

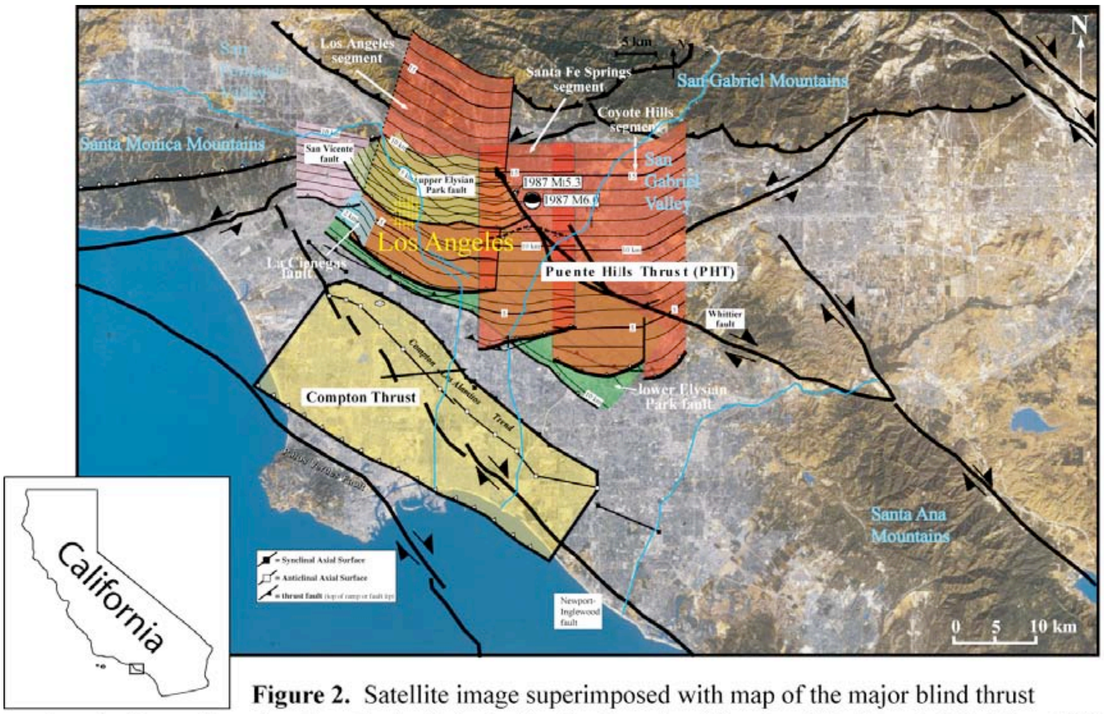

Figure 2. Satellite image superimposed with map of the major blind thrust systems in the northern Los Angeles basin including the Compton Thrust and the Puente Hills Thrust (PHT). Also shown are other major thrust and strike-slip systems. The cross-hatched yellow lines indicate the location of downtown Los Angeles. Blue lines indicate the location of the Los Angeles River (west), San Gabriel River (middle), and Santa Ana River (east).

Our study focused on an attempt to document the details of surface deformation caused by large-magnitude ruptures of the Compton thrust fault, which was originally identified by *Shaw and Suppe* [1996] using petroleum-industry seismic reflection profiles and well data. The seismic data define a growth fault-bend fold associated with the base of the NE-dipping thrust ramp, which extends northwest-southeast for 40 km along the western edge of the Los Angeles basin (Figure 2). Based on the geometry of the growth fold, Shaw and Suppe (1996) proposed two viable geometries for the underlying fault, both including a fault ramp that dips to the northeast at 15-40°. Shallow splays of this fault have been imaged in 3D seismic data from the Wilmington oil field (*Shaw et al., 1999*). One of these structural solutions implies that the ramp merges at depth with a detachment system that extends to the northeast beneath the central basin, whereas the alternative solution implies that structure is underlain by a southwest-dipping fault, forming an active structural wedge. Seismic reflection and well data reveal compelling evidence for

Pliocene and Pleistocene activity (*Shaw and Suppe, 1996*). Specifically, these data demonstrate that the fault has generated more than 500 m of uplift at the base of the Quaternary across the 1- to 2-km-wide fold limb associated with the base of the fault ramp. Based on this structure, Shaw and Suppe (1996) determined a long-term average slip rate for the fault of 1.4 ± 0.4 mm/yr.

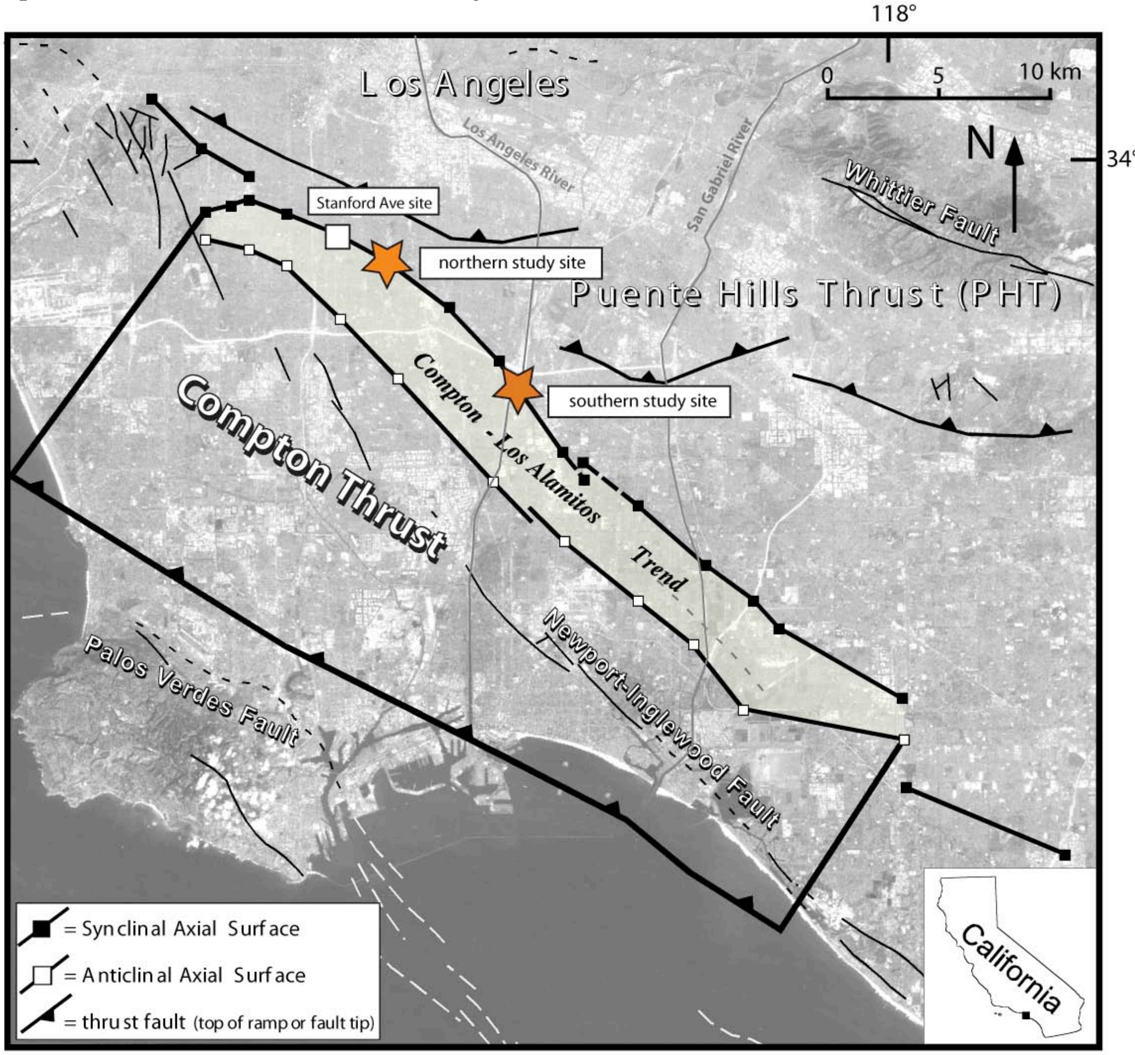

Figure 3. Map of the Compton thrust ramp showing two study sites (orange stars). Teeth denote top of blind thrust ramp, which dips gently (24°–29°) to the northeast. "Compton-Los Alamitos trend" denotes location of strata folded above the change in dip at the base of the Compton ramp. Our study sites lie along the active synclinal axial surface that records folding of strata as they are thrust southwestward across the change in dip at the base of the thrust ramp. Also shown (white square) is the Stanford Avenue study site of Leon et al. (*2009*) 2 km northwest of our proposed northern site.

Prior to initiating the proposed work, our long-term collaborators John Shaw (Harvard), Tom Pratt (USGS) and we undertook a systematic, multi-disciplinary study of the location, geometry, structural evolution, state of activity, and paleoseismology of the

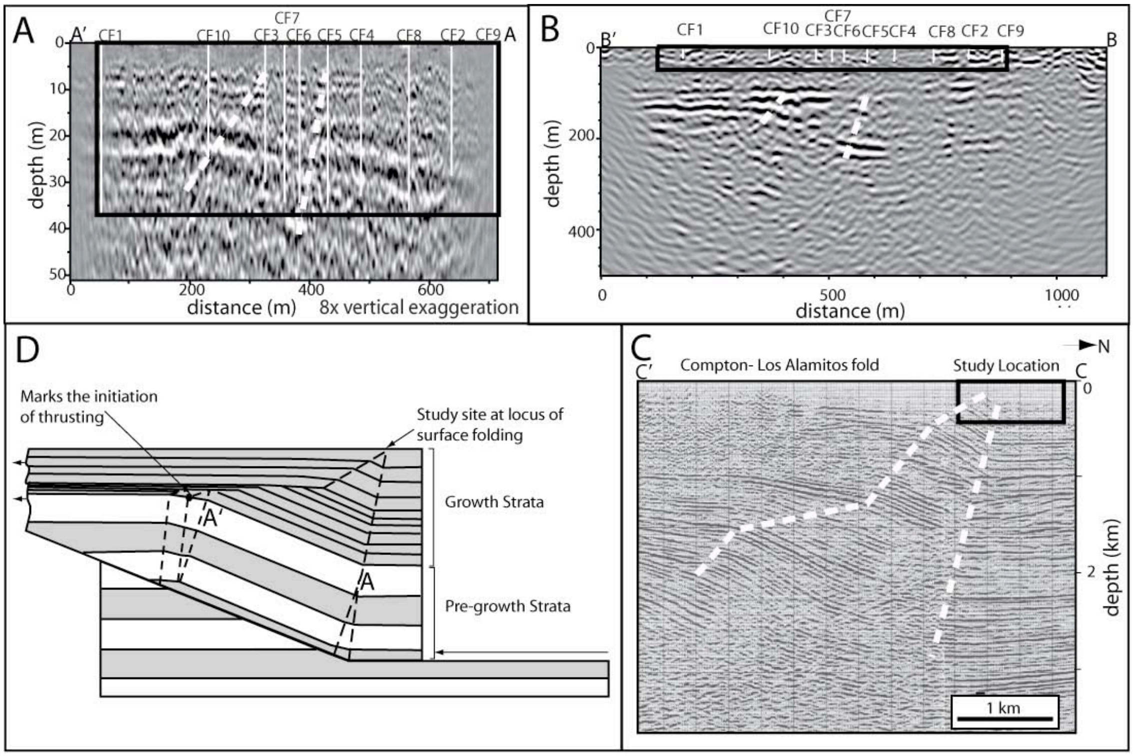

Figure 4. Petroleum-industry and high-resolution seismic reflection data showing the upward-narrowing growth triangle associated with slip through the backlimb axial surface (*Leon et al., 2009*). (A) Hammer-source seismic reflection profile (migrated; 8x vertical exaggeration). The prominent reflector at 10–17 m depth shows the kink band clearly. Thin, vertical, white lines show borehole locations. Dashed white lines represent active, synclinal and inactive, anticlinal axial surfaces. Black box indicates location of borehole transect cross-section in figure 5. (B) Weight-drop source seismic reflection profile (depth migrated). No vertical exaggeration. The prominent reflector at 120-200 m depth shows the kink band well. The sub-horizontal reflector at about 100 m depth is likely the water table, as velocities above the reflector are consistent with unsaturated strata. The reflector also cuts across the geologic structure consistently defined by the underlying reflectors and overlying drill hole data, as would be expected for the water table. Thin, vertical, white lines show borehole locations. Dashed white lines represent active, synclinal and inactive, anticlinal axial surfaces. Black box indicates location of hammer-source profile shown in figure 4A. (C) Seismic reflection image of the backlimb fold structure showing upward-narrowing zone of active folding (growth triangle) delimited by sharply defined axial surfaces (*Shaw and Suppe, 1996*). No vertical exaggeration. Dashed white lines represent active, synclinal and inactive, anticlinal axial surfaces. Back box indicates location of weight-drop source profile shown in figure 4B. (D) Fault-bend fold model of backlimb fold structure of the Compton thrust fault with discrete axial surfaces yielding an upward-narrowing fold limb in growth strata (*Shaw and Suppe, 1996*).

Compton Thrust. These studies included acquisition of high-resolution seismic reflection and borehole data at several sites to define the stratigraphic and structural evolution of young folded strata from several hundred meters depth to the surface (Figures 3–5). Our studies reveal an upward-narrowing growth triangle associated with slip through the backlimb synclinal axial surface that encompasses almost all (>85-90%) of the total structural relief of the anticline built by slip on the Compton thrust ramp (*Leon et al., 2009*).

In addition to the high-resolution seismic reflection data, at several sites we also acquired fault-perpendicular transects of continuously cored boreholes across the zone of active folding. These boreholes reveal deformed Holocene-latest Pleistocene strata that record recent activity on the Compton thrust. The earthquake-by-earthquake growth of the back-

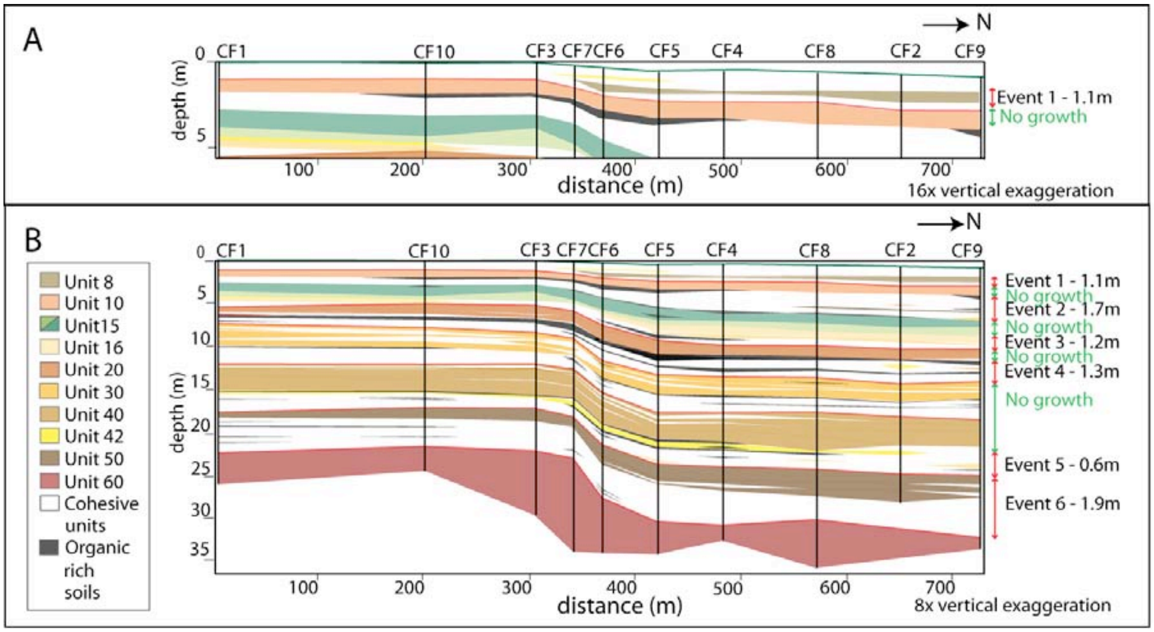

Figure 5. (A) Borehole results from the shallowest part of the Stanford Avenue transect showing details of stratigraphic onlap during most recent uplift event (Leon et al., 2009)(16x vertical exaggeration). Green sub-horizontal line is the present ground surface. (B) Cross section of major stratigraphic units showing form of the fold during latest Pleistocene-Holocene time, as well as discrete intervals of growth that mark the development of paleo-fold scarps (8x vertical exaggeration). Colors denote different sedimentary units, with sands that can correlated across the entire transect denoted by units of 10 (i.e., Units 10, 20, 30, etc.). Thin red lines mark the tops of major sand and gravel units. Double-headed red vertical arrows along the right side of the figure show the stratigraphic ranges of intervals of sedimentary thickening (i.e., growth) across the transect, with the uplift in each event shown the right of each arrow. Double-headed green vertical arrows show intervals of no sedimentary growth during periods of inter-seismic structural quiescence. The fold scarp that grew during the most recent Compton thrust earthquake is particularly well defined (Figure 5A). The Unit 10 sand (orange in figure 5A) does not change thickness across the transect, suggesting that it was deposited during a period of quiescence at the stream gradient. This unit was folded during the most recent event, producing a 1-m-high, north-facing fold scarp. This now-buried scarp was subsequently on-lapped by the Unit 8 sand (brown in figure 5A). Later deposition occurred at the near-horizontal stream gradient, burying the fold scarp. Thus, the uplift event that produced the fold scarp occurred after deposition of the Unit 10 sand, and before deposition of the Unit 8 sand. Radiocarbon dates on charcoal and bulk-soil samples constrain the age of the MRE a Stanford Avenue site to between 750 to 1750 calendar years ago (*Leon et al., 2009*).

limb fold of the Compton Thrust is illustrated especially well by data from our earlier Stanford Avenue site, located along the backlimb of the northern part of the Compton Thrust. As shown in figure 5, the young deformed strata there are marked by discrete sequences that thicken repeatedly across a buried series of fold scarps. Leon et al. (2009) interpreted the intervals of growth as occurring after the formation of now-buried paleo-fold scarps that formed during uplift events generated by seismic slip on the underlying Compton thrust ramp. In each of these, fold growth has uplifted the strata to the south of the zone of active folding, resulting in a north-facing fold scarp that was subsequently onlapped by the next-youngest stratigraphic unit. These growth intervals are separated from one another by layers that do not change thickness across the length of our borehole transects, reflecting deposition at the near-horizontal paleo-floodplain stream gradient. These constant-thickness intervals thus record periods of structural quiescence between major uplift events.

Results of Earlier Site Reconnaissance

As part of an earlier phase of this project, we undertook an exhaustive search for any sites along the active axial surfaces (locus of recent folding) above the Compton and Puente Hills blind thrust faults that exhibited sufficient open space to excavate a continuous, deep trench to expose the details of recent co-seismic folding. Using maps of the location of the active axial surfaces above these two major faults based on previous analysis of petroleum-industry seismic reflection data conducted by our long-term collaborator John Shaw (Harvard University), we found only two sites that met these criteria.

These sites, which are located 8 km apart along the northern segment of the Compton Thrust ramp, are uniquely sited to the research. Not only do they lie on the recently active, near-horizontal floodplain of the nearby Los Angeles River, leading to deposition of numerous laterally extensive, organic-rich, near-horizontal sedimentary beds, but seismic reflection data from near these sites document a well-defined, upward-narrowing growth triangle that extends to the surface in the middle of two of the only sites in this densely urbanized region that offer sufficient open space to undertake the large excavations we proposed. Such large trenches are necessary to fully expose the entire width of the now-buried fold scarps that formed during the most recent large-magnitude blind thrust earthquake on the Compton Thrust.

Colonel Leon Washington Park study site, Los Angeles County, California

Our primary proposed study site was located in Colonel Leon H. Washington Park in the unincorporated Florence-Graham area administered by Los Angeles County 10 km south of downtown Los Angeles (Figure 1)(33° 57.37’N; 118° 14.61’W). This site seemed ideal for our proposed studies because: (a) it lies within a Los Angeles County-administered park with sufficient open space to excavate our proposed mega-trench directly above the up-dip surface projection of the locus of recent folding above the backlimb of the Compton blind thrust; and (b) the site is located in the very low-gradient

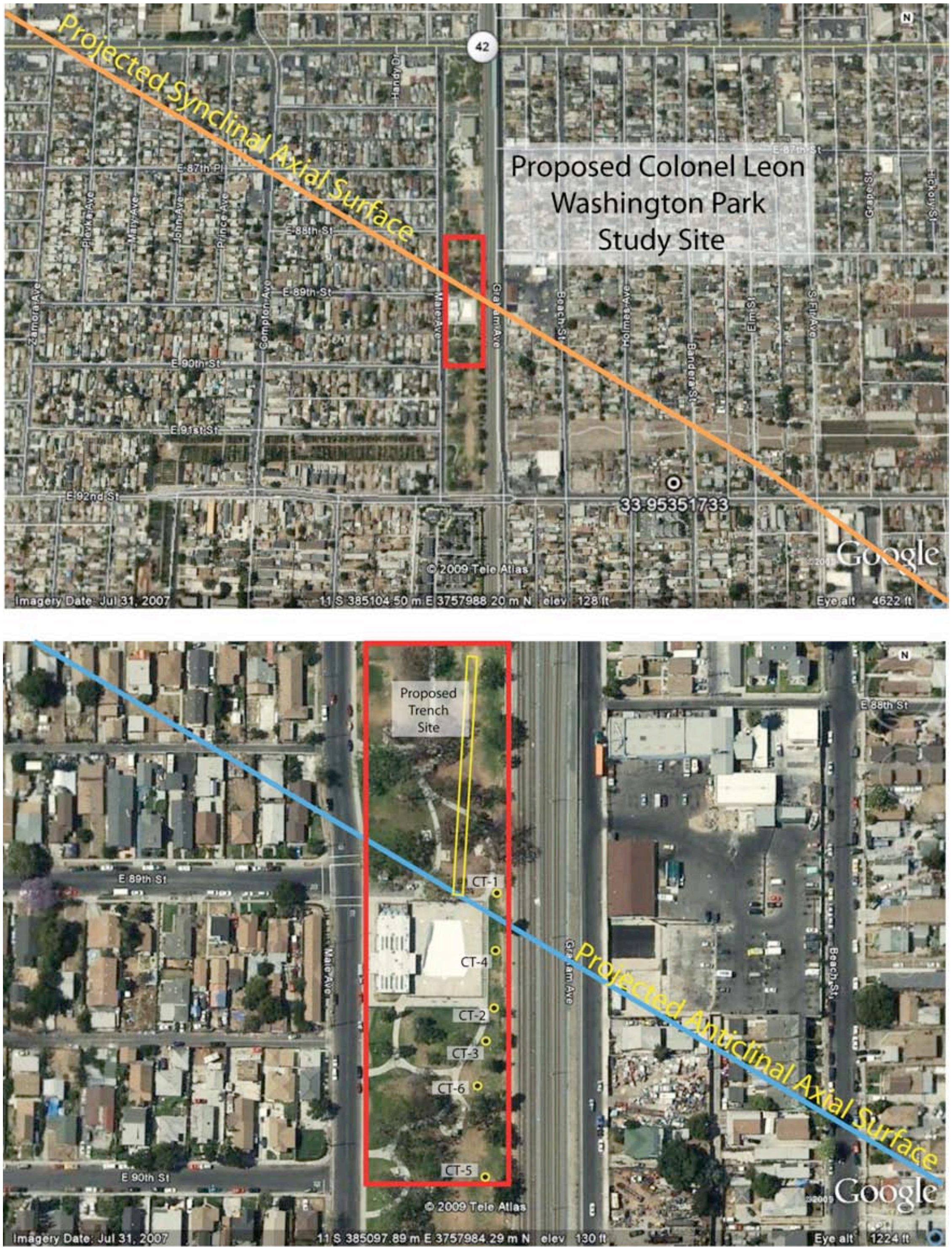

Figure 6. Location maps of the Colonel Leon H. Washington Park site. Yellow-and-black dots in lower image denote locations of our six reconnaissance boreholes, shown in cross section in figure 7. Yellow box in lower image shows our originally proposed mega-trench location. Note the scarcity of open spaces of sufficient size to excavate a 100-m-long mega-trench along the projected surface trace of the zone of active folding in this densely urbanized environment.

floodplain of the Los Angeles River, which our previous investigations, including at the nearby site of Leon et al. (2009), 2 km to the NW, showed were characterized by relatively continuous deposition of well-bedded clays, silts, and sands during the Holocene. Specifically, at the Stanford Avenue site Leon et al. (2009), using a combination of structural modeling of industry seismic reflection data, analysis high-resolution seismic reflection data that we collected, and a N-S series of continuously cored boreholes, documented evidence for at least six stratigraphically discrete folding and uplift events that they interpreted as evidence for co-seismic uplift during large-magnitude ($M_w \geq 7$) latest Pleistocene-Holocene earthquakes on the underlying Compton blind thrust fault, including evidence for the most-recent folding event at 1.5-2.0 m depth ca. 700 to 1750 years ago (Figures 3-5). Based on the similarities with the Leon et al. (2009) site, we expected to find similarly favorable sedimentologic and stratigraphic conditions at the Colonel Leon Washington Park site.

After a lengthy permitting period during an earlier phase of this project, we were eventually granted permission by Los Angeles County to drill a N-S transect of continuously cored boreholes along the up-dip projection of the Compton blind thrust backlimb active axial surface determined from the industry seismic reflection data. As shown in figure7, these boreholes revealed the expected excellent stratigraphy of thinly bedded clays, silts, and fine-grained sand units that was markedly similar to the shallow part of the section exposed at the Stanford Avenue site of Leon et al. (2009) 2 km to the NW. Indeed, there seemed to be an almost 1:1 match of sands and intervening finer-grained units, including two near-black, organic-rich clays that Leon et al. (2009) interpreted as paleo-marsh deposits. The marked similarity in these stratigraphic sections suggests that, as might be expected on such an extensive, low-gradient floodplain, sheet-like deposition of individual units extended over wide areas.

The boreholes also revealed that we intersected the well-defined inactive anticlinal axial surface of the Compton Thrust backlimb fold extending to depths of <3 m near the middle of the borehole transect (Figure 7). Specifically, the anticlinal axial surface at this site is defined by the inflection point between the nearly flat-lying deposits exposed at the southern end of the transect and north-dipping strata to the North. Moreover, the shallowest ~1.5 m of strata extended completely across the fold without changing their thickness or near-horizontal dip. The base of these flat-lying strata thus mark the event horizon associated with folding during the most-recent large-magnitude earthquake on the Compton Thrust, indicating that we encountered evidence for folding during the MRE at shallow depths amenable to standard trenching procedures. However, our data also revealed that the borehole transect did not extend far enough north to intersect the active synclinal axial surface. Inasmuch as the key goal of this phase of the project was to identify the exact locations of the synclinal and anticlinal axial surfaces (which define the northern and southern limits of the north-dipping folded panel), we went back to Los Angeles County and requested permission to extend our borehole transect farther north to ensure that we had mapped the full extent of the shallowest folding in the most recent major earthquakes on the Compton Thrust, which would define the exact location for siting our proposed mega-trench.

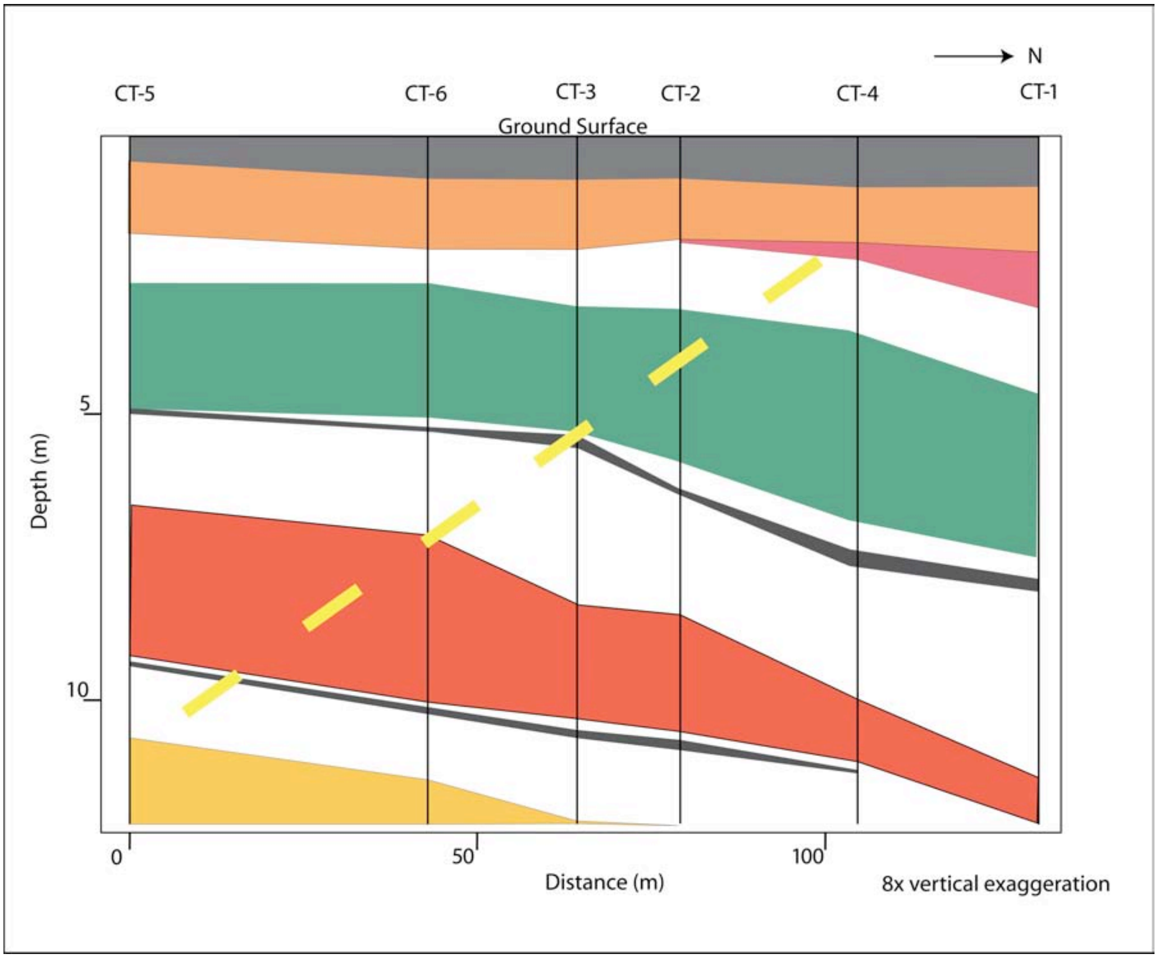

Figure 7. Cross-section of preliminary Colonel Leon H. Washington Park borehole transect showing geometry of young deformed sediments (location of boreholes shown on figure 6) (8X vertical exaggeration). North is to the right. Borehole locations are shown in figure 6. Colored units are very fine-grained sand units. Interbedded cohesive clay and silt units are shown as white or medium gray. The two thin black layers are organic-rich marshy paleosols. Note the northerly dip of strata in northern part of transect, and sub-horizontal bedding to south. The dashed yellow line that separates these two dip domains is the inactive anticlinal axial surface (i.e, the top of the fold); the active, synclinal axial surface (base of the fold scarp) lies to the north of the borehole transect. We were subsequently denied permission by Los Angeles County to extend our borehole transect farther North to define the position of the synclinal axial surface more precisely before we excavate our mega-trench.

After another very lengthy permitting process, Los Angeles County surprisingly denied our request for continued research at the park, with the County Counsel noting that the project was deemed to have no “public benefit”. After receiving this rather shocking news, which marked a 180° shift from our previous interactions with County staff, we requested and were granted a meeting with County personnel at the park to explain that our study did, in fact, have considerable “public benefit”. We subsequently met with County staff and explained repeatedly that our project was solely focused on the benefit of the public, and we detailed to them the specific results we anticipated and their expected use in facilitating a better understanding of the threat posed by ground deformation beneath the metropolitan area in future large-magnitude earthquakes on the Compton, and by extension, other blind thrust faults beneath the metropolitan region. At the conclusion of that meeting, the County staff promised that they would re-evaluate our request and bring it back to the County Counsel. We never heard back from them, and they ignored repeated email and phone requests for updates of the status of this re-review of our permit application. In the face of this intransigence on the part of LA County staff charged with reviewing our application, we eventually gave up and turned our attention to our secondary target site, along the southern part of the Compton Thrust (detailed below).

Central Compton Thrust site

Our secondary study site was located along the western edge of the active channel of the Los Angeles River between Lynwood and Paramount, California, 1 km south of the intersection of the 105 and 710 freeways, and 17 km SSE of downtown Los Angeles (33° 54.28'N; 118° 10.95'W). We did not start with this site because of concerns that: (1) its position adjacent to the active channel of the river might result in a sediment accumulation rate that was too fast to preserve evidence for the fold scarp that developed in response to the most recent Compton Thrust earthquake at depths shallow enough to be reached with the proposed mega-trench; and (2) the river might have eroded, or at least partially eroded, any fold scarp that might have been created during Compton Thrust paleo-earthquakes. Nevertheless, faced with the intransigence of LA County personnel in allowing access to our primary Colonel Leon Washington Park site in Florence-Graham, we decided to attempt preliminary investigations at the southern site to determine whether it was suitable for the proposed mega-trench work.

Research at this site required permissions from the California Department of Transportation (Caltrans), the owners of the parcel. Although Caltrans employees were very helpful with permitting, it was a lengthy process that took many months. After eventually receiving permission from Caltrans, as shown in figure 8 we drilled a N-S transect of four continuously cored, 15-m-deep hollow-stem boreholes across the surface projection of the locus of active folding revealed by the petroleum industry seismic reflection data (Shaw and Suppe, 1996; J. Shaw, written communication 2009).

As shown in figure 9, these boreholes revealed a flat-lying section of fine- to coarse-grained sands interbedded with finer-grained, silt- and clay-dominated sections. Because of the lack of deformation observed in this flat-lying section, we did not date any charcoal from the section, so the ages of these strata are not directly constrained. But the absence of any evidence for significant soil development, coupled with the highly friable character of all sediments encountered that were coarser-grained than silt, indicates that the entire section is likely late Holocene in age. This suggests that it was deposited quite rapidly, which is in keeping with the proximity to the active channel of the Los Angeles River only a few 10s of meters east of the site behind an artificial berm.

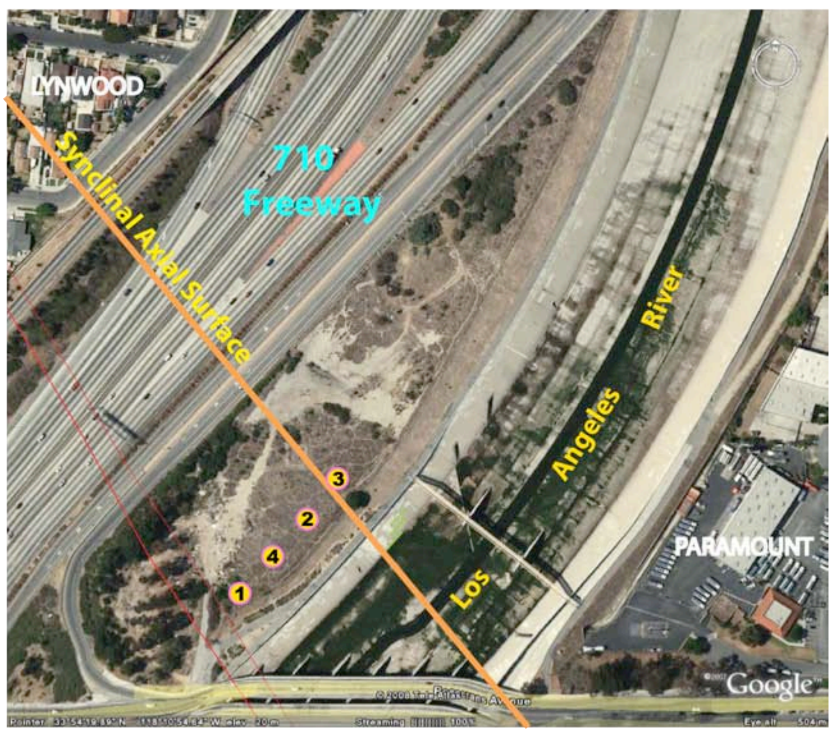

Figure 8. Locations maps of our 710 Freeway study site. The site is a large open field located between the freeway and the Los Angeles River. Orange line shows surface projection of active, synclinal axial surface (i.e., the base of the fold scarp). Numbered yellow dots show locations of the four continuously cored boreholes shown in figure 9. The transect was designed to capture the NNE-dipping panel of strata folded in recent earthquakes on the Compton blind thrust.

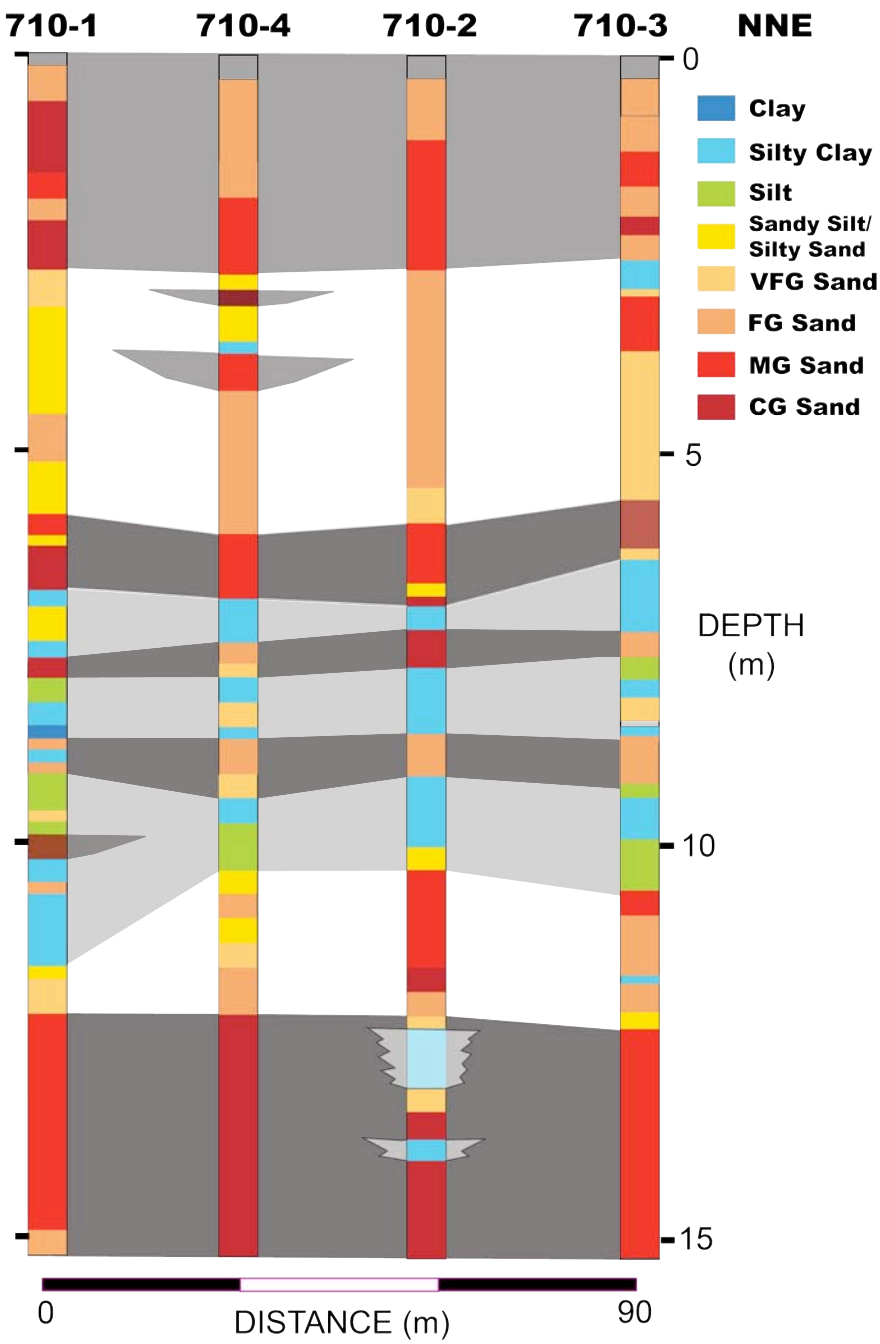

Figure 9. Stratigraphic correlations between the four continuously cored boreholes drilled at the 710 Freeway site (shown with 12X vertical exaggeration). Locations of boreholes shown in figure 8. Different colors denote different grain sizes, as shown by color scale to right of cross section. Note that the. If these strata had been folded above the NNE-dipping underlying Compton Thrust ramp, as expected given their proximity to the active, synclinal axial surface of the Compton Thrust, we would expect them to be NNE-dipping (i.e., dipping down to the right in this cross section). Instead, the entire section of sand-rich and silt-rich fluvial strata are notably flat-lying. Dark- and pale-gray shading denote prominent sand-rich and silt-rich sections, respectively.

The absence of any evidence of folding at this site indicates that either: (1) the sediment accumulation rate at this site is so fast that evidence of the most-recent folding event is buried below the 15 m depth of our borehole transect, rendering the site beyond the depth limits of conventional trenching; or (2) the active axial surface actually projects upward for the base of the Compton Thrust ramp slightly to the north of the study site; this possibility would require that the active, synclinal axial surface dips more gently than the best dip estimate based on analysis of the petroleum-industry seismic reflection data (J. Shaw, pers. Comm., 2009). In either event, we realized after reviewing our boreholes results that the site is unsuitable for excavation of the proposed mega-trench.

Following this second disappointment, we conducted a renewed comprehensive reconnaissance, both in the field and using satellite data, of potential sites along the entire lengths of the surface traces of recent folding above not only the Compton Thrust, but the Puente Hills Thrust, as well. We were unable to locate any other sites where there was sufficient land to excavate our proposed mega-trench.

Conclusions

Although we conducted extensive initial studies at our preferred study site at Colonel Leon Washington Park above the northern part of the Compton blind thrust axial surface, revealing that it was an ideal location for the proposed research, we were eventually denied permission to continue our studies by Los Angeles County after we had invested considerable time, effort, and funds to prove the site. In the event that Los Angeles County eventually comes to the conclusion that the proposed study actually does have some “public benefit”, contrary to their current assessment, the Colonel Leon H. Washington Park locality will provide an excellent, proven site for future studies of the exact geometry and nature of the fold scarps that have formed in past large-magnitude earthquakes on the Compton blind thrust fault.

Despite the disappointing lack of our anticipated results from this study, our work at the Florence-Graham site does reveal some of the details of the fold scarp that developed in the most-recent large-magnitude earthquake on the Compton Thrust. Specifically, our closely spaced boreholes demonstrate that the scarp was at least 25 m wide. Moreover, our documentation of the the southern part of the fold scarp that formed during the MRE on the Compton blind thrust fault reveals at least 0.7 m of structural relief developed in the MRE folding event across the >25 m-wide fold scarp. These observations, though minima, demonstrate that the MRE along the Compton Thrust generated large displacements on the order of $\geq$ 1.5-2 m along at least the 2.2 km length of the fault between the Stanford Avenue study site of Leon et al. (2009) and the Florence-Graham site.

These observations, coupled with evidence from Leon et al. (2009) for even larger events earlier in the Holocene, demonstrates that recurrence of such an event beneath the metropolitan Los Angeles area would result in uplift of $\geq$1-2 m of the block above the

NE-dipping Compton Thrust ramp, resulting in the generation of NE-facing fold scarps that will extend for 10s of km through the densely urbanized region underlain by the Compton Thrust (Figure 1). Moreover, it is important to note that, aside from the obvious surface deformation hazards that would result from the uplift and tilting of the ground surface above such co-seismic fold scarps, because of the geometry of the Compton Thrust, it is the block to the SW of the axial surface that will be uplifted in future events. This is unfortunately opposite to the natural flow direction of all gravity-fed systems in the southwestern part of the Los Angeles metropolitan region, and we anticipate that all gravity-fed systems (e.g., water pipes, sewer pipes, and indeed, the Los Angeles River itself) will pond and potentially even flow backwards against the northeast-facing, southwest-side-up fold scarps.

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