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Final Report

Investigation of Possible Quaternary Faulting in the City of Memphis and Shelby County, Tennessee

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Abstract

Structure contour maps, geologic cross sections, and three-dimensional ArcScene computer models were constructed of the tops of the Pliocene Upland Complex, Eocene-Oligocene Upper Claiborne Group, and Eocene Lower Claiborne Group from geotechnical borings and water wells within Southern Shelby County, Tennessee. These data sets reveal northeast-trending faults that are linked by east-west-trending faults to form fault bounded blocks. Shallow seismic reflection profiling using both P-wave and S-wave techniques imaged the Ellendale fault, Shelby Farms Fault, and Hollywood Fault zone. The more deeply imaged Ellendale Fault indicates reactivation and inversion of a steep normal fault and this may by typical of all the faults mapped in this study. Electrical conductivity and borings were acquired over the projected traces of the Ellendale and Shelby Farms faults to define trench targets. Three trenches were opened, two on the trace of the Ellendale Fault and one on the trace of the Shelby Farms fault. These trenches revealed minor earthquake liquefaction dikes, but no definitive Holocene faulting.

Introduction

Various types of research have investigated earthquake hazards within the city of Memphis and Shelby County, Tennessee, primarily driven by the threat of the New Madrid seismic zone (NMSZ) (Fig. 1) (Van Arsdale, 1997). This research includes, for example, geological (Kingsbury and Parks, 1993; Broughton et al., 2001; Yates et al., 2003; Van Arsdale et al., 2003a; Cox et al., in press), geophysical (Cramer et al., 2003; Gomberg et al., 2003; Williams et al., 2001), and engineering (Romero and Rix, 2001; Schneider et al., 2001; Liao et al., 2002; Van Arsdale et al., 2003b; Williams et al., 2003) investigations. The only detailed subsurface map of all of Shelby County is a U.S. Geological Survey Water-Resources Investigations map by Kingsbury and Parks (1993) that shows several faults displacing Eocene strata. However, the possible presence of Quaternary faulting beneath Shelby County has only recently been addressed (Velasco et al., 2005). In this current project, we reinterpreted over 600 geotechnical borings and water wells of southern Shelby County and made structure contour maps of the tops of the Pliocene Upland Complex, top of the combined Eocene-Oligocene Jackson Formation and Upper Claiborne Group (herein called the Upper Claiborne Group), and the top of the Eocene Lower Claiborne Group to determine if they have been displaced by faulting. In addition, seismic reflection profiles, electrical conductivity surveys, shallow borings, and trench excavations were acquired across three Shelby County faults.

Geology of the Northern Mississippi Embayment and Shelby County, Tennessee

The Mississippi Embayment (Fig. 1) is a broad south-southwest plunging shallow trough filled with poorly consolidated Late Cretaceous and Tertiary shallow marine and fluvial sediments (Bushchbach and Schwalb, 1984; Van Arsdale and Ten Brink, 2000). Beneath the northwestern portion of the Mississippi embayment is the Reelfoot rift (Fig. 1), a southwest-trending graben approximately 65 km wide and 320 km long. This rift is a late Precambrian-Early Paleozoic aulacogen (Ervin and McGinnis, 1975; Braile et al., 1982). The rift geometry has been defined primarily through gravity and magnetic surveys (Hildenbrand et al., 1977) with the eastern rift margin in Tennessee being recently mapped with seismic reflection profiles (Parrish and Van Arsdale, 2004). Most NMSZ earthquakes occur within the rift (Fig. 1). However, the southeastern margin of the Reelfoot rift has been tectonically active in Quaternary time along the Crittenden County fault zone, 25 km northwest of Memphis (Crone, 1992; Luzietti et al., 1992; Williams et al., 1995). Additional Quaternary faulting has been identified within the southeastern margin of the Reelfoot rift at Porters Gap and it has been proposed that this rift margin may currently be accumulating strain (Cox et al., 2001; Cox et al., in press).

The stratigraphy of the upper 1 km in the northern Mississippi embayment (Fig. 2) consists of Cambrian carbonate rocks unconformably overlain by Upper Cretaceous marine and terrestrial sands, silts, and clays in turn overlain by Tertiary marine and terrestrial sands, silts, and clays (Van Arsdale and TenBrink, 2000). The shallow stratigraphy beneath the city of Memphis and Shelby County, Tennessee, consists of the Eocene Claiborne Group, which is subdivided in ascending order into the Memphis Sand, Cook Mountain Formation (clay, silt, and minor sand and lignite), and Cockfield

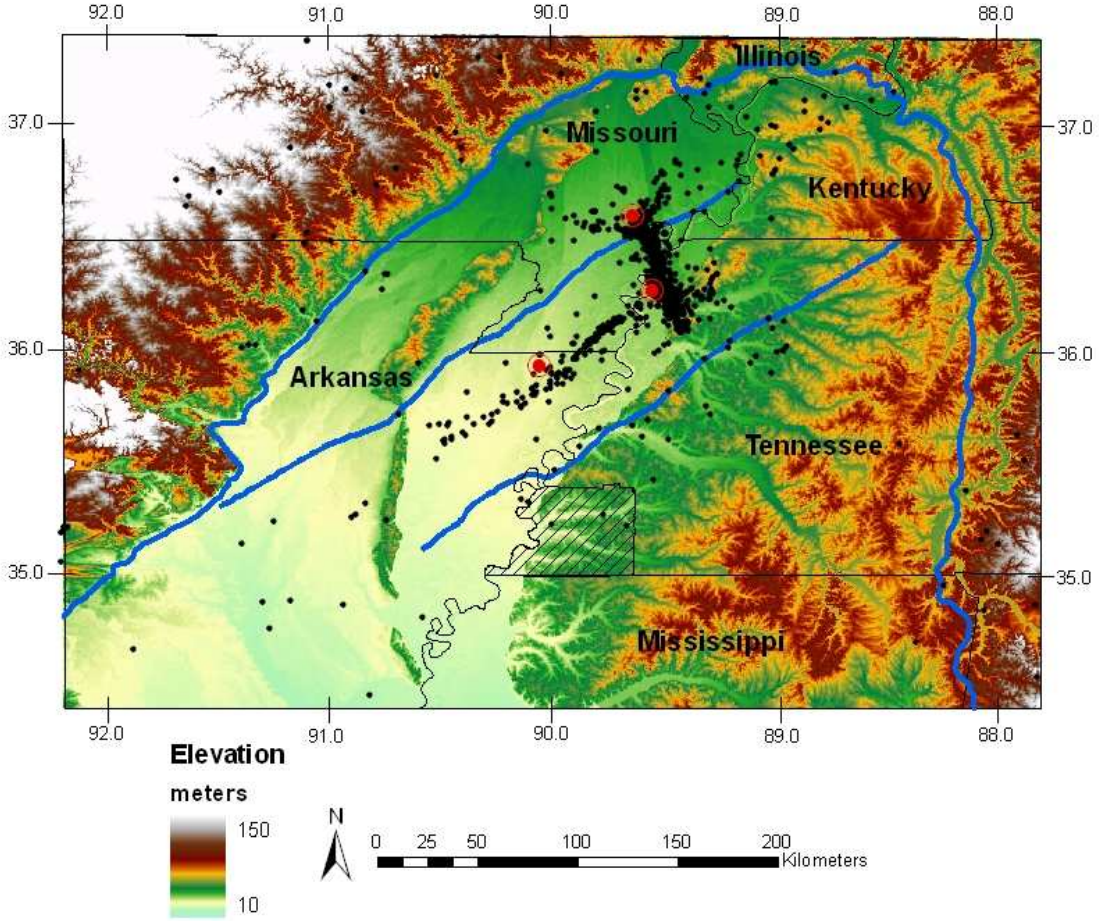

Figure 1. Digital elevation model of the Mississippi embayment. The embayment margins are outlined in blue and the two northeast-trending blue lines are the Reelfoot rift margins. The black dots are earthquake epicenter locations of the New Madrid seismic zone from 1975 to 2005 (from NCEER). The three red dots represent estimated epicenter locations for the Dec. 16, 1811 (southern), Jan. 23, 1812 (northern), and Feb. 7, 1812 (central) earthquakes. Shelby County, Tennessee is represented by the hashed polygon (from R. Csontos, personal communication).

Formation (sand, silt, and clay). The Eocene/Oligocene Jackson Formation exists beneath extreme northwest Shelby County and is included in the Upper Claiborne in this report. In the Mississippi River valley, the Upper Claiborne is overlain by Mississippi River alluvium, but beneath Memphis and Shelby County it is overlain by the Pliocene Upland Complex (Autin et al., 1991; Van Arsdale et al., in press). This is a fluvial sand and gravel deposit of the ancestral Ohio River that has an erosional upper and lower contact. The Upland Complex is overlain by up to three Pleistocene loess deposits. Late Pleistocene and Holocene alluvium of the Loosahatchie River, Wolf River, and Nonconnah Creek are locally inset into the loess and Upland Complex in Shelby County.

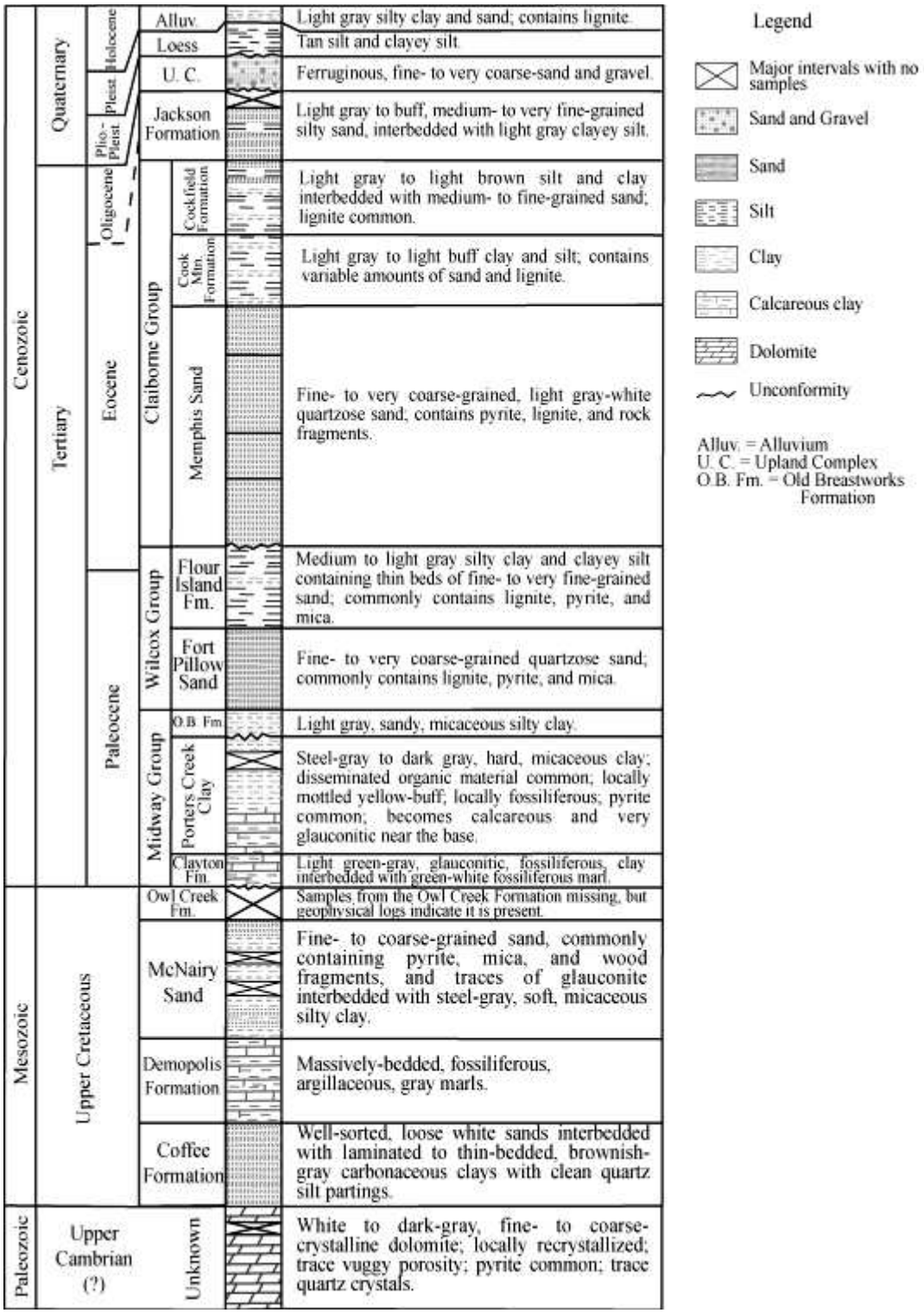

Figure 2. Stratigraphic column for the Memphis, Tennessee region (Crone, 1981).

New Madrid Seismic Zone and Shelby County, Tennessee

The principal seismic activity within the upper Mississippi embayment is located within the Reelfoot rift along the NMSZ (Fig. 1). NMSZ seismicity occurs primarily along three trends that define a northeast-trending right-lateral strike-slip fault system with a compressional left-stepover zone (Russ, 1982; Schweig and Ellis, 1994). Geological and geophysical evidence for neotectonic activity in this area has been accumulating rapidly over the past two decades. The geological features indicative of earthquakes include liquefaction, landslides, faulting, and warping of the ground surface (Schweig and Van Arsdale, 1996).

Shelby County, Tennessee, and the city of Memphis are located near the southeastern margin of the Reelfoot rift and the NMSZ (Fig. 1) and earlier regional studies have proposed faults beneath Shelby County. Johnson et al. (1994) produced a basement fault map from geophysical data, in which Shelby County is transected by several basement tectonic structures. Kingsbury and Parks (1993) have mapped faults from water well data that displace the Eocene Upper Claiborne Group. One of their mapped faults corresponds with a recently identified northeast-striking down-to-the-west fault called the Ellendale fault. The Ellendale fault appears to displace the Upland Complex by up to 20 m (Yates et al., 2001; Velasco et al., 2005).

Numerous sand dikes formed by earthquake liquefaction have been found in cut banks along the Wolf and Loosahatchie rivers in Shelby County (Van Arsdale et al., 1998; Broughton et al., 2001). The dikes were probably emplaced during the 1811-1812 New Madrid earthquakes since the dikes show no weathering effects and some extrude onto the Wolf River flood plain surface. However, it is also possible that this liquefaction was caused by local earthquakes, perhaps in Shelby County (Broughton et al., 2001).

Indirect evidence of Holocene movement on a minor fault within the Ellendale Fault zone, subsequently renamed the Shelby Farms Fault by Deen (2006), was observed in a cut-bank exposure on the Wolf River (Velasco et al., 2005). At this exposure, an anticline composed of flood plain sands has a wavelength of approximately 100 m, minimum amplitude of 4 m, and a hinge oriented 10^0N7^0W. Flat lying clayey silt overbank sediments overlie and truncate the folded point bar sands. A 1 m wide earthquake liquefaction intrusion (sand dike) was also observed above the crest of the anticline in the overbank sediments. ^{14}C dates indicate the anticline originated between 390 $\pm$ 60 AD and 450 $\pm$ 50 AD and the sand dike occurred post 450 $\pm$ 50 AD. Shallow P-wave and S-wave seismic reflection profiles indicate the anticline extends down at least 60 m into the Lower Claiborne Group, is over 1 km in length, and is thus tectonic in origin. It is believed that the anticline formed during ~ 5 m of Holocene right lateral strike slip on the Shelby Farms Fault (Velasco et al., 2005). These observations suggest that faults beneath the City of Memphis and Shelby County may have Holocene displacement.

Methods

The purpose of this study was to, 1) remap the subsurface geology of the southern 2/3 of Shelby County using existing geotechnical borings and water wells, 2) acquire additional seismic reflection profiles across suspected faults, and 3) determine if the Ellendale, Shelby Farms, and Memphis faults displace Holocene sediments.

Structure Contour Maps and Geologic Cross Sections

Over 600 geotechnical boring and water well logs were acquired from private geotechnical companies (Hall Blake and Associates, PSI, and Tristate), government organizations (U.S. Geological Survey, Tennessee Department of Transportation, Shelby County Health Department, U.S. Army Corps of Engineers, and the Tennessee Department of Environment and Conservation), and from Ng et al. (1989). (These well and boring data are available at http://gwidc.gwi.memphis.edu/website/introduction.) Structure contour maps were made of the top of the Upland Complex, Upper Claiborne Group, and Lower Claiborne Group using ArcGIS and ArcScene. The contour interpolation method used was kriging. Kriging is a geostatistical interpolation technique based upon a generalized least-square algorithm, using semi-variograms (measure of the continuity of elevation expressed as an average squared difference between measured elevations at different locations) as weighting functions. This method produces a statistically unbiased estimate and the least amount of undesirable artifacts except at map edges (Krajewski et al., 2005). To define the fault locations in this current study, each surface was evaluated independently by posting the depths of each borehole on the gridded surfaces and then identifying locations where abrupt linear breaks were present. The interpreted faults were then used to break each map into separate fault bounded blocks that were then gridded and contoured independently.

Geologic cross-sections were constructed from the structure contour maps by exporting the ArcGIS format files to Excel for plotting.

Subsurface 3-D Modeling of Southern Shelby County

The 3-D capabilities of ArcScene proved valuable in visualizing the subsurface stratigraphy and faults beneath the city of Memphis and southern Shelby County. In this report we illustrate a 3-D model of the stratigraphic horizons broken by faults.

Seismic Reflection Survey Acquisition

In the Shelby Farms study area a total of four shallow S-wave and four shallow P-wave seismic reflection surveys were acquired between 2002 and 2004 (Velasco, 2002; Velasco et al., 2005). In this study a deeper P-wave line, Moore_P, was acquired along Moore Road and processed by Edward Woolery. James Harris subsequently acquired the Moore_S shallow S-wave profile across the western end of the Moore_P line to image the shallower section. James Harris also acquired the shallow James_S, S-wave reflection profile at the James Road study area. All of the seismic profiles were processed using the

following basic sequence: trace editing, notch filtering (if necessary), common midpoint sorting, pre-stack filtering, automatic gain control, velocity analysis, normal move out correction, common midpoint stacking, and post sack filtering (if necessary).

Depth Conversion of Seismic Reflection Profiles

To gain a better understanding of the geology along Moore Road in Shelby Farms a depth converted geologic cross section was made by combining three profiles. The Moore_P, Moore_S, and Shelby01 reflection profiles were spatially referenced, depth converted, and compiled into one geologic cross section. The James_S profile acquired in the James Road study area was also depth converted to create a geologic cross section (Deen, 2006).

Electrical Conductivity Surveys

Electrical conductivity surveys were acquired using a Geonics EM31 to determine if there was a near surface (upper 4 m) expression of the faults. The conductivity meter applies an electromagnetic inductive technique that continually transmits an electrical current that measures resistivity variations generated by changes in spontaneous potential of the near surface sediments (Sharma, 1997). This instrument has a maximum depth penetration of 5.6 m below the surface. A 4 m by 4 m measurement spacing was used in the data collection. The values recorded by the instrument are measured values and are not calibrated values. Contour maps reveal conductivity gradients that were subsequently compared to the projected faults.

Shallow Borehole Transects

Shallow borehole transects were acquired in areas where electrical conductivity gradients aligned with the projected fault planes observed in the shallow seismic profiles. A trailer mounted Giddings soil testing rig was used to acquire the shallow boreholes. Hydraulic pressure was applied and the hollow core barrel was pushed into the ground thereby filling with sediment. The sediment sample was then removed from the core barrel and placed in split PVC pipes. This process was repeated until the Giddings rig reached its maximum depth of penetration, which varied depending on the local sediment properties. Upon reaching the maximum depth, the level of penetration was recorded as well as the borehole's GPS coordinates. After acquiring the last borehole of each transect each borehole was labeled, aligned in cross sectional view, split, measured, and logged. Detailed borehole logs were created with descriptions of lithology, color, grain size, degree of mottling, and unit thickness. In areas where the shallow stratigraphic sequence was well constrained an auger attachment was used on the Giddings rig to determine the elevation of a prominent sand contact.

Trench Excavation and Logging

Trenches were excavated in locations where a fault was interpreted in the seismic reflection data and electrical conductivity survey and there was a distinct change in the geology between adjacent Gidding's rig boreholes. Having a location with all of these

criteria identifies a target location where near surface displacement could be observed. Three trenches ranging from 3 to 3.5 m deep by 12 to 30 m in length were excavated and logged during this study. The trench walls were then scraped and logged on a meter grid.

Six carbon samples were obtained from stratigraphic units logged in the trench and were C^{14} dated by Beta Analytic Laboratory in Miami, Florida (Deen, 2006).

Results

Structure contour maps (Figs. 3-6), geologic cross sections (Fig. 7), and a three-dimensional ArcScene computer model (Fig. 8) of the tops of the Pliocene Upland Complex, Eocene Upper Claiborne Group, and Eocene Lower Claiborne Group were constructed from approximately 600 geotechnical borings and water wells within the southern 2/3 of Shelby County. Shallow seismic reflection profiling using both P-wave and S-wave techniques imaged the Ellendale, Shelby Farms, and Hollywood Fault zones. Subsequent electrical conductivity, Giddings rig borings, and trenching studies were conducted on these faults.

Structure Contour Maps, Cross Sections, and ArcScene 3-D Geologic Model

Structure contour maps of the tops of the Lower Claiborne Group, Upper Claiborne Group, and Upland Complex were constructed for southern Shelby County (Figs. 4-6). These maps reveal major N30^{0}E striking down-to-the-west faults that are linked by shorter down-to-the-north faults. Cross-sections A-A' and B-B' (Fig. 7) reveal that some of these faults displace the Pliocene Upland Complex and others only cut the Claiborne Groups.

The ArcScene 3-D geologic model illustrates the tops of the Lower Claiborne (blue), Upper Claiborne (green), and Upland Complex (purple), and vertical fault panels (gray) at 75 times vertical exaggeration (Fig. 8). This ArcScene model may be viewed as a rotating Southern Shelby County, TN 3-D model at: https://umdrive.memphis.edu/rvanrsdl/public/

Shelby Farms Study Area Seismic Reflection Profiles and Geologic Interpretation

A shallow P-wave and a shorter S-wave seismic reflection line were acquired across the Ellendale fault (Figs. 9-11). When combining these reflection lines with lines acquired in earlier studies a composite geologic cross section was constructed (Fig. 12). As revealed in this geologic cross section, the Ellendale is a normal fault at depth and a reverse fault near the surface. Also evident are the west-verging gentle anticline and east-dipping Shelby Farms fault.

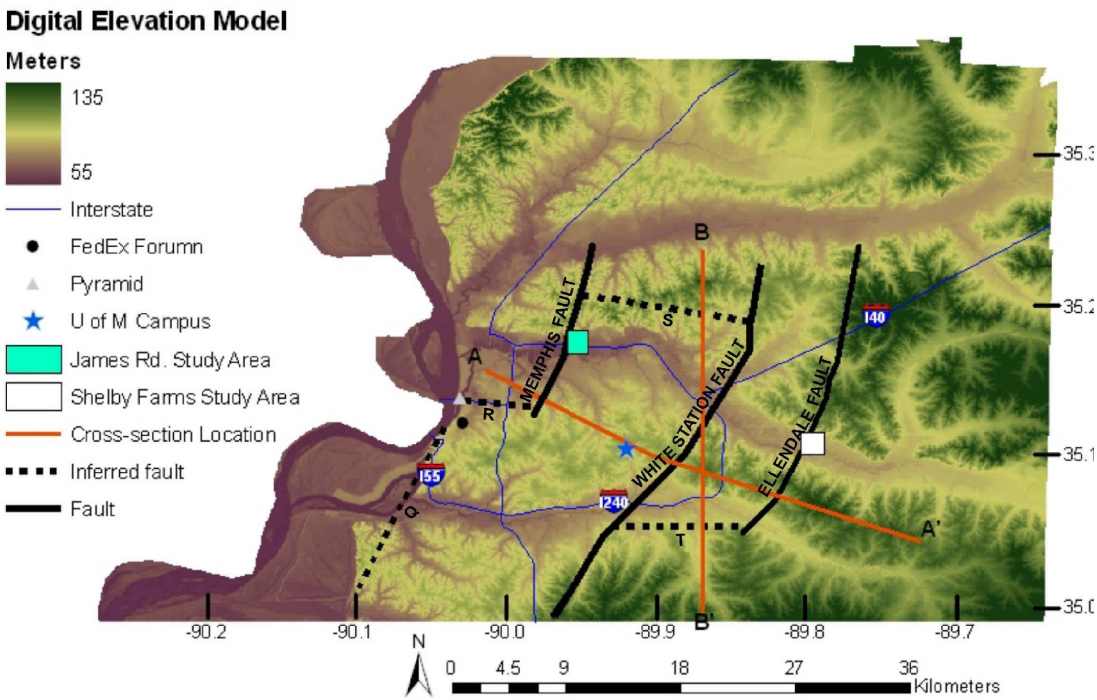

Figure 3. Digital Elevation Model of Shelby County showing faults identified in this study, projected to the ground surface.

Near Surface Investigations of the Shelby Farms Fault

To determine if the Shelby Farms Fault displaces Holocene sediments of the Wolf River flood plane an electrical conductivity survey, shallow borehole transect, and a trench excavation were conducted across the fault.

Electrical Conductivity Survey and Shallow Borehole Transect Across the Shelby Farms Fault

A 40 m by 100 m electrical conductivity survey was acquired over a portion of a low Wolf River terrace where the Shelby Farms Fault was projected to pass (Figs. 9 and 13). The electrical conductivity survey identified an abrupt gradient that corresponded with the projected trace of the Shelby Farms Fault. This gradient suggested that within the upper 4 meters, low conductivity sandy sediments were present to the west and higher conductivity clayey sediments were present to the east of the projected fault trace thus suggesting vertical displacement. Therefore, a shallow borehole transect was acquired perpendicular to the observed conductivity gradient (Fig. 13). The observed lithologies represented a near surface soil profile that developed in loess and overbank silt overlying point bar sands. The constructed cross-section suggested vertical displacements of the

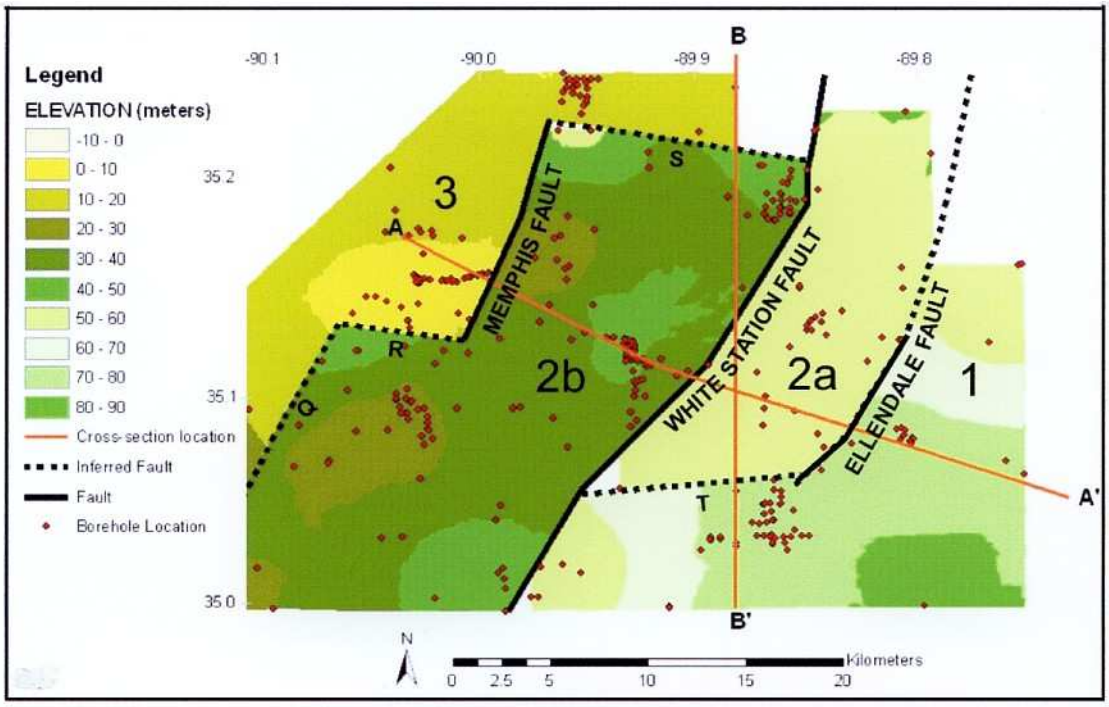

Figure 4. Southern Shelby County structure contour map of the top of the Eocene Lower Claiborne Group (Memphis Sand) that has been divided into fault blocks (1-3).

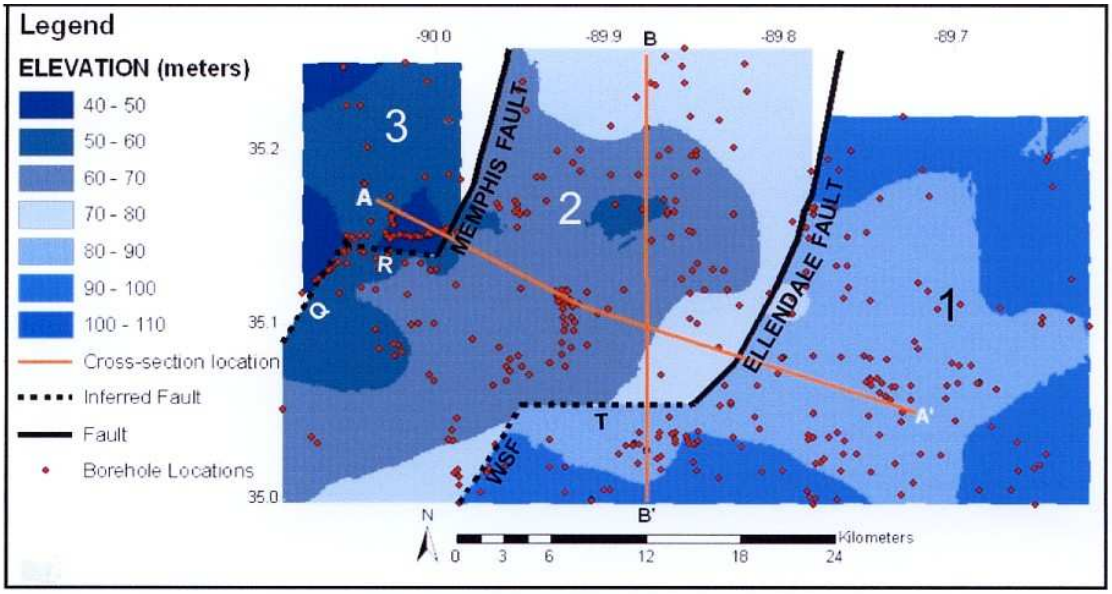

Figure 5. Southern Shelby County structure contour map of the top of the Eocene Upper Claiborne Group that has been divided into fault blocks (1-3).

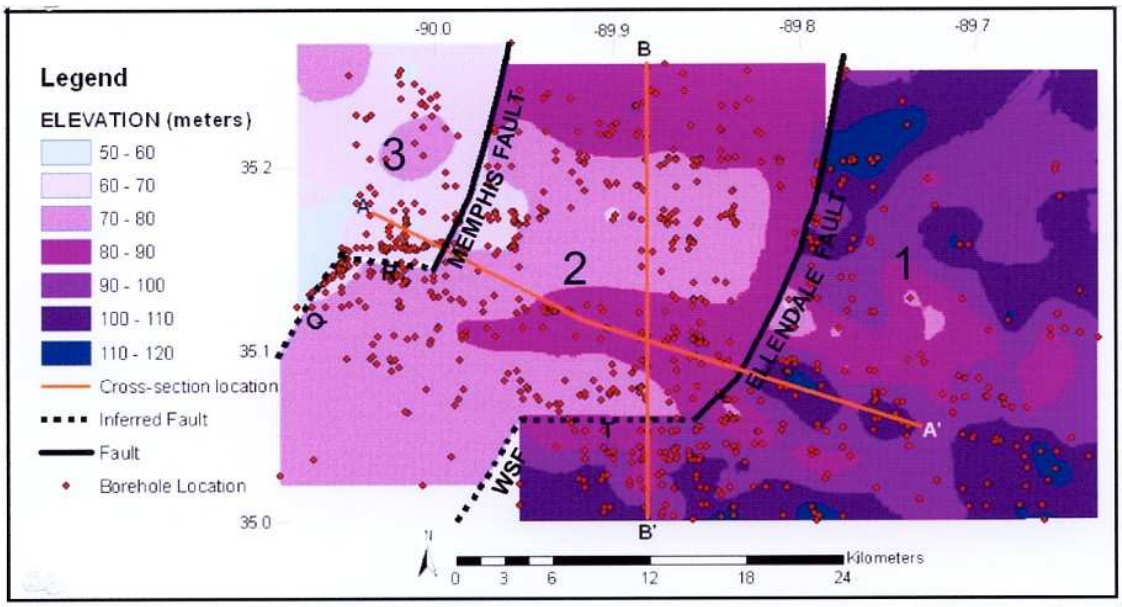

Figure 6. Southern Shelby County structure contour map of the top of the Pliocene Upland Complex that has been divided into fault blocks (1-3).

correlated lithologies. The apparent faulting correlated with the conductivity gradient and the location where the Shelby Farms Fault was projected to pass through based on the seismic reflection profiles.

Shelby Farms Fault Trench One

Shelby Farms Trench One was excavated between boreholes E and B of Figure 13 and was approximately 29 m in length and 3 m deep (Figs. 14 and 15). ^{14}C samples revealed that the trench sediments are early Holocene (~ 8000 BP). A general description of the profile observed in Shelby Farms Trench One follows from the uppermost unit to the basal unit: Ap horizon of moderate yellowish brown (10yr 5/4) silt, E/B horizon of very light gray (N7) silt with moderate mottling and an irregular lower contact caused by crotivina (crawfish borrows), an oxidized zone of silt, and a basal B horizon of light olive gray (5y 6/1) silt with moderate mottling. Shelby Farms Trench One, with a depth of only 3 m, did not expose the lower sand unit found in the borings and Trenches Two and Three. In Shelby Farms Trench One a distinct change occurred at the surface in the soil profile at meter 7 (Fig. 15). A concave up accumulation of cross-bedded sandy silt was present at the top of the trench at this location and appears to be a cut-and-fill paleochannel. At this same location, but in the basal unit of the trench, the intense mottling in the western portion of the trench abruptly stopped. These two features being in the same location suggested possible faulting. This possible fault zone was further investigated by acquiring sediment samples on each side of the zone for grain size analyses and by collecting core-plugs within the possible shear plane. Particle size analyses reveal a slight change in particle size across the prospective shear plane; however, the plugs did not reveal any fault zone fabric (Deen, 2006).

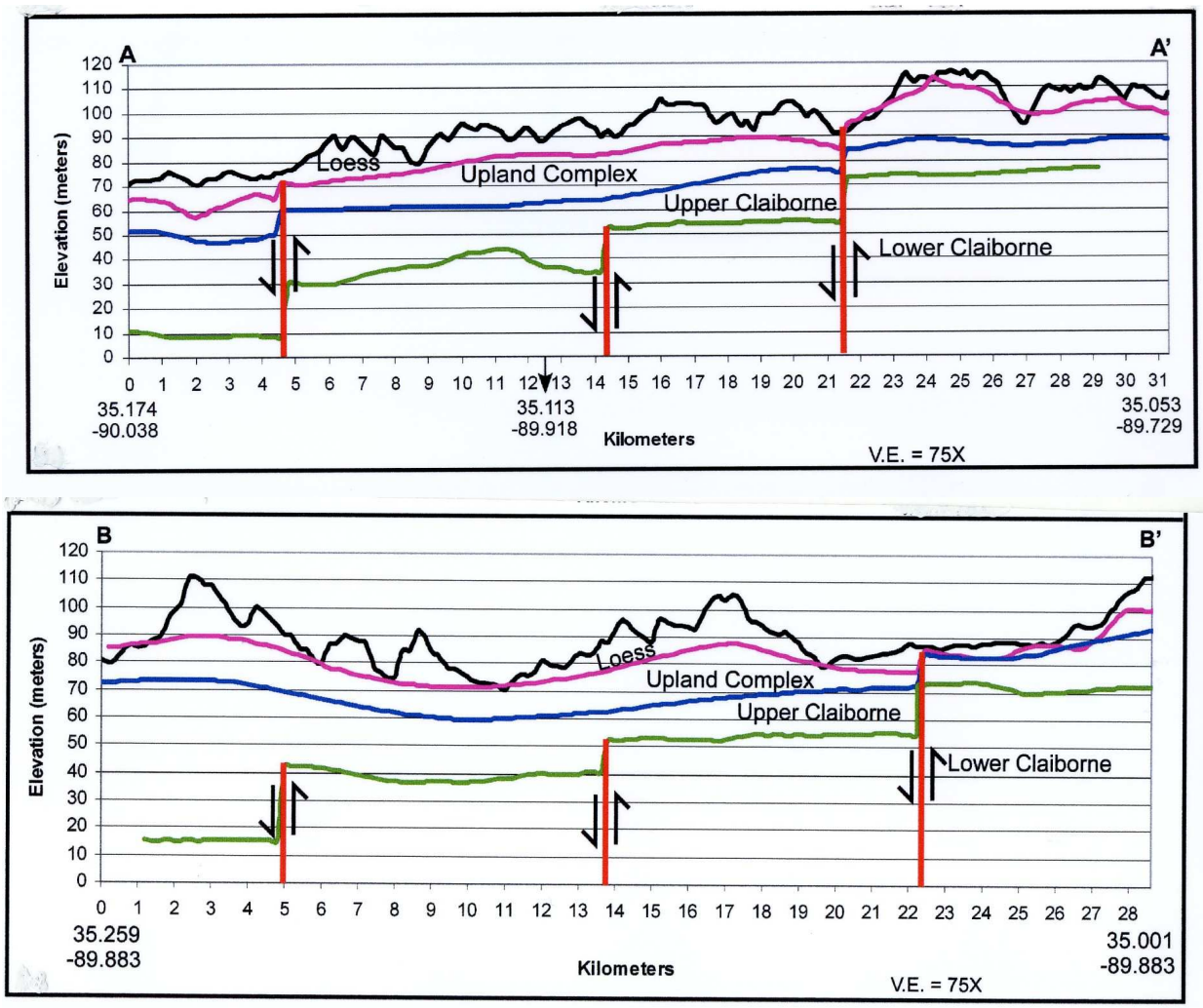

Figure 7. West-east cross section A-A' and north-south cross section B-B'. See Figures 3-6 for locations.

Near Surface Investigations of the Ellendale Fault

Electrical Conductivity Survey and Shallow Borehole and Auger-hole Transect Data.

A 150 m by 350 m electrical conductivity survey was acquired to the south of Moore Road where the Ellendale Fault trace was projected to the surface (Figs. 9 and 16). A northeast trend of low conductivity appears to align with the surface projection of the Ellendale Fault zone. To determine if the abrupt changes in electrical conductivity represent vertical displacements within the near surface stratigraphy, shallow borehole and auger-hole transects were acquired across the conductivity anomalies (Fig. 16). The observed lithologies represented a soil profile that developed in a loess and or overbank deposit and the lower most sand is a point bar sand of the Wolf River. The locations of suggested displacement between boreholes M and L in the northern most transect and R,

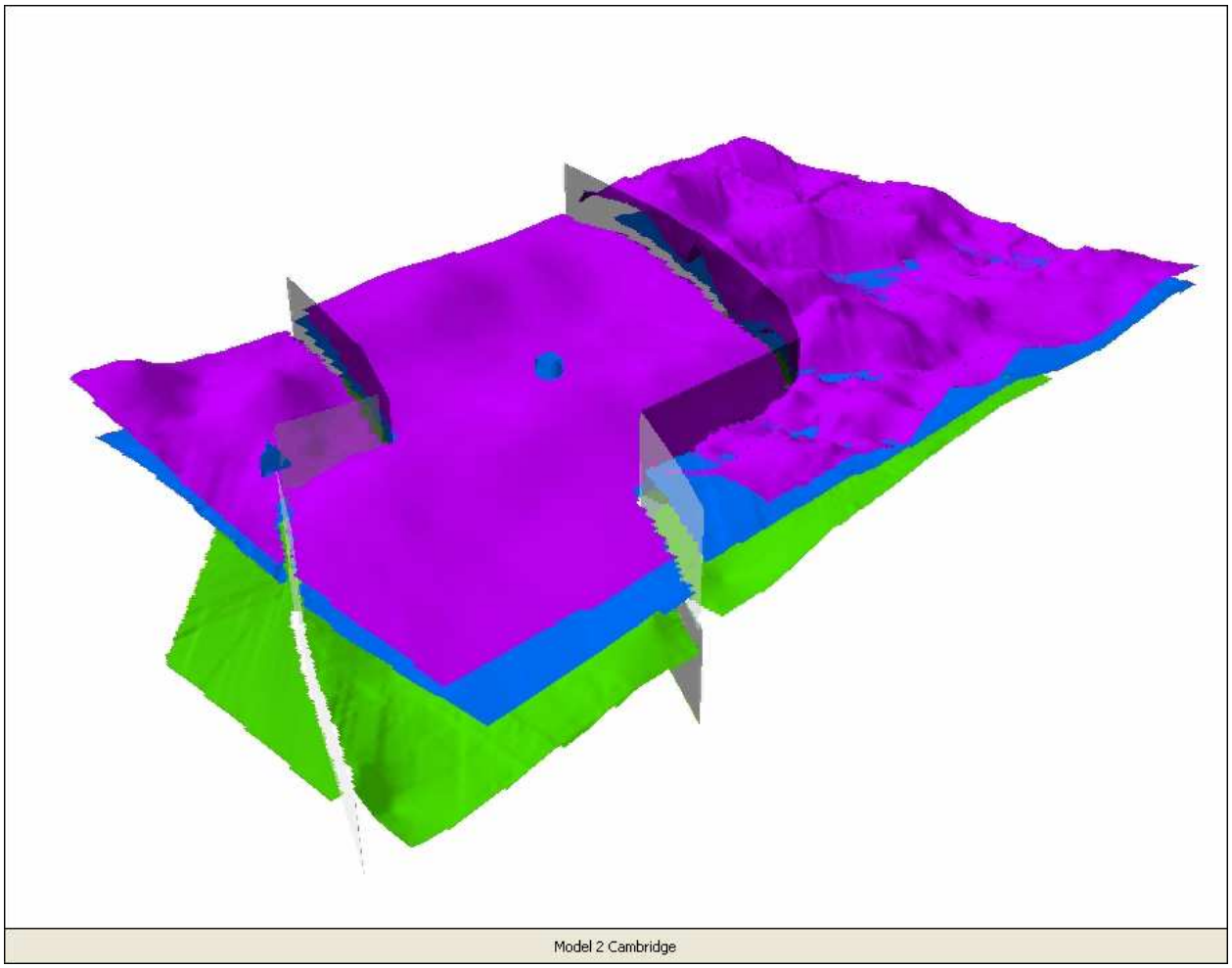

Figure 8. ArcScene map of the tops of the Upland Complex (purple), Upper Claiborne (blue), and Lower Claiborne (green). Vertical gray panels are faults. The University of Memphis (cylinder) and the Pyramid Entertainment Center (pyramid) float in space on the loess covered landscape (not shown) (from Deen, 2006). This model may be viewed as a rotating Southern Shelby County, TN 3-D model at: https://umdrive.memphis.edu/rvanrsdl/public/

and O in the central transect were our primary trench targets. However, this property is used for agricultural experiments and permission was not granted to excavate in these areas. Permission was granted to excavate trenches at our secondary targets located further to the south along the auger-hole transect.

Shelby Farms Trenches Two and Three

Shelby Farms Trench Two was excavated between auger-holes DD and BB (Figs. 17 and 18) to capture the suggested displacement present on the sand-silt contact. The profile exposed in Trench Two was 12 m in length and 3.5 m deep and consisted of the following units form top to bottom: Ap horizon of moderate yellowish brown (10yr 5/4) silt, E/B horizon of very light gray (N7) silt with moderate mottling and an irregular

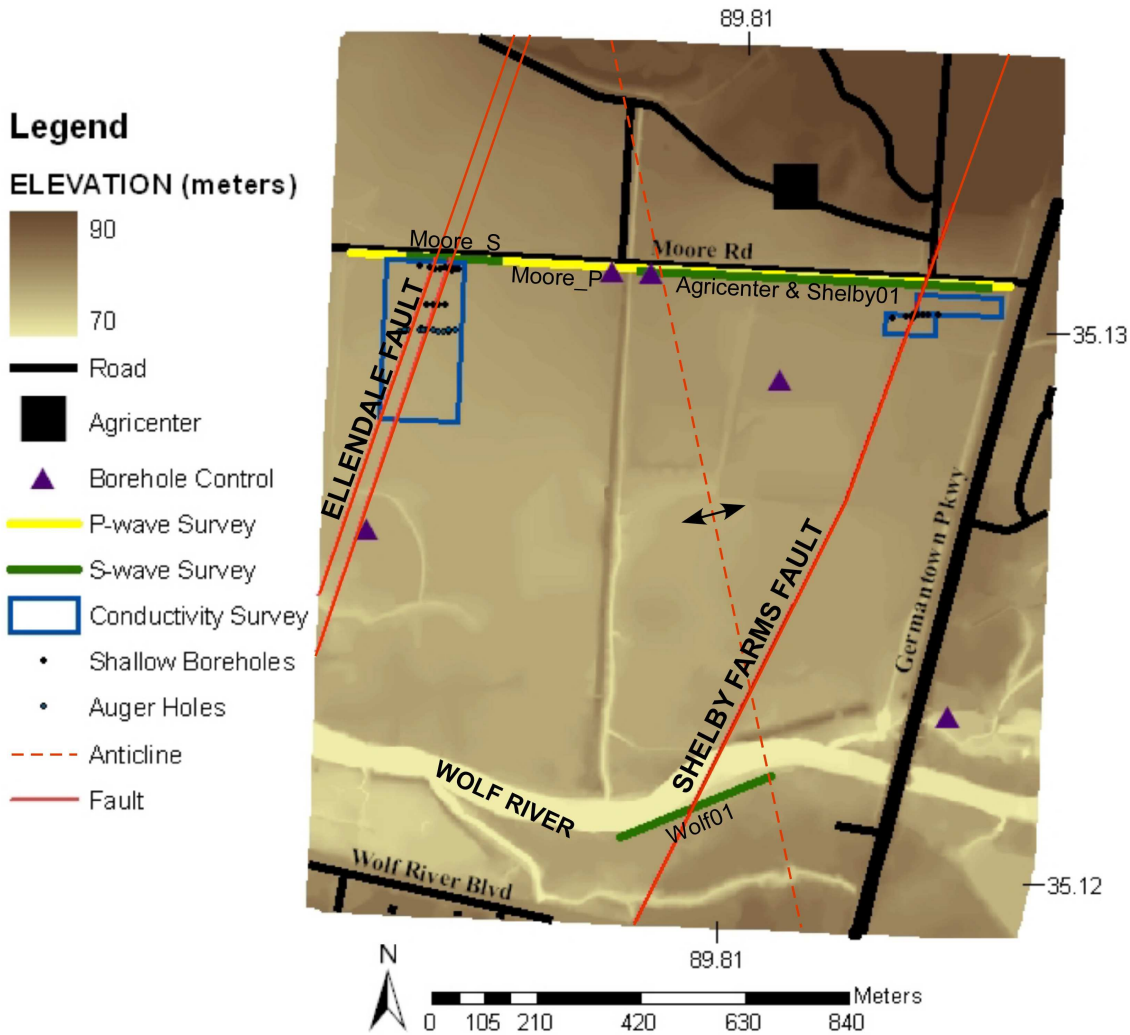

Figure 9. Shelby Farms study area. Located in white box of Figure 3.

lower contact caused by crotivina (crawfish borrows), an oxidized zone of silt, B horizon of light olive gray (5y 6/1) silt with moderate mottling, and a basal unit of light olive gray sandy silt with yellowish gray (5y 8/1) and grayish orange (10yr 7/4) fine to medium grained point-bar sand deposits.

Shelby Farms Trench Three (Figs. 17 and 19) was 25 m in length and 3.5 m deep and exposed the same stratigraphic sequence as Shelby Farms Trench Two; however, the Wolf River point-bar deposits were more prevalent in this trench and oxidization was present in the shallowest portions of the point-bar deposits. Also, minor liquefaction deposits were present within the point-bar deposits of Trench Three indicating seismic shaking. Sediments within the two trenches are early to mid Holocene (~ 9000 – 7000 B.P.).

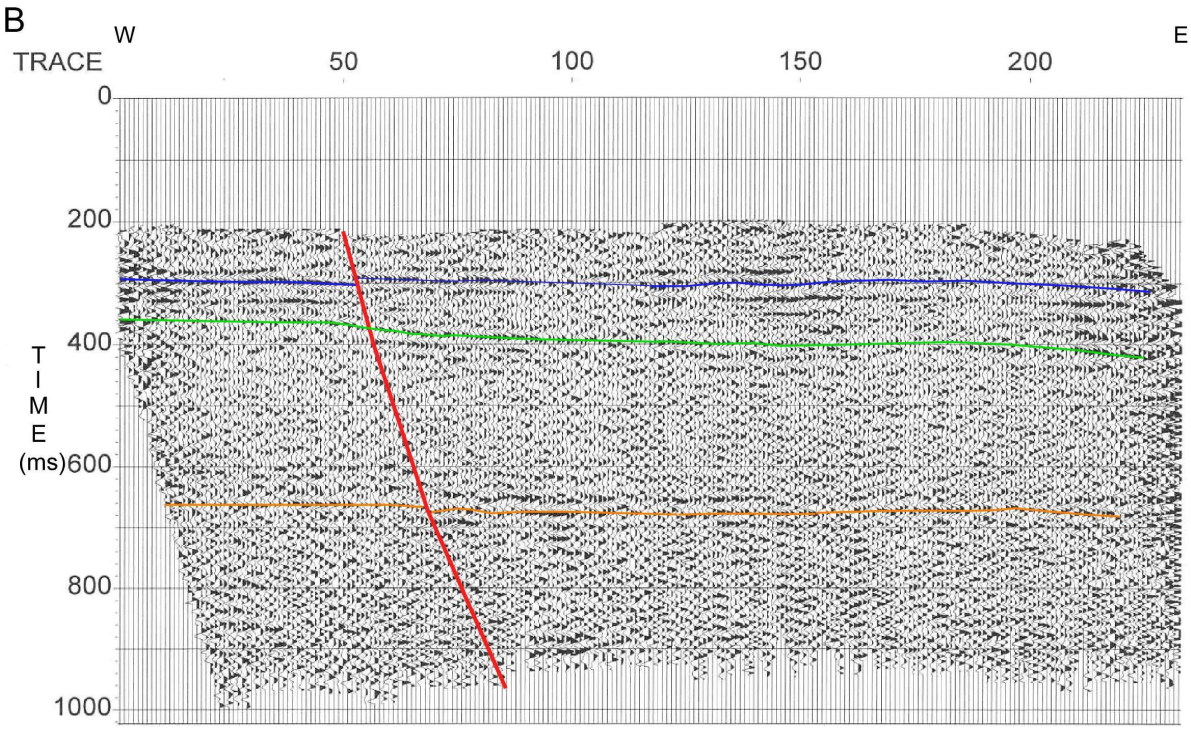

Figure 10. Moore_P is a P-wave seismic reflection profile. The blue highlighted reflector is ~ 235 m below the surface and represents the top of the Flower Island Formation. The green highlighted reflector is ~290-330 m below the surface and represents the top of the Fort Pillow Formation. The orange highlighted reflector is ~615 m below the surface and probably represents the top of the McNairy Sand. A prominent fault is present at CMP 50 that shows normal displacement at depth and reverse displacement up-section. Located along yellow line in Figure 9.

James Road Study Area

The James Road study area (Fig. 20) was defined based on its proximity to the Memphis Fault proposed by Velasco et al. (2005). The data collected within this study area included a shallow S-wave seismic reflection profile and an electrical conductivity survey. Permission to core and trench at this site was denied.

Shallow S-wave Reflection Profile

A shallow S-wave seismic reflection profile, James_S, was acquired along James Road (Figs. 20 and 21) to gain a better understanding of the local stratigraphy and determine if any fault displacement was present. This profile was 470 meters in length. The resolution in the James_S profile is lost 350 m from the western end, due to a large culvert beneath the surface (represented by the ? in Figure 21). Two faults were imaged in this profile and define a fault zone herein named the Hollywood Fault zone. The western bounding fault displaces the Pliocene Upland Complex. The eastern fault does

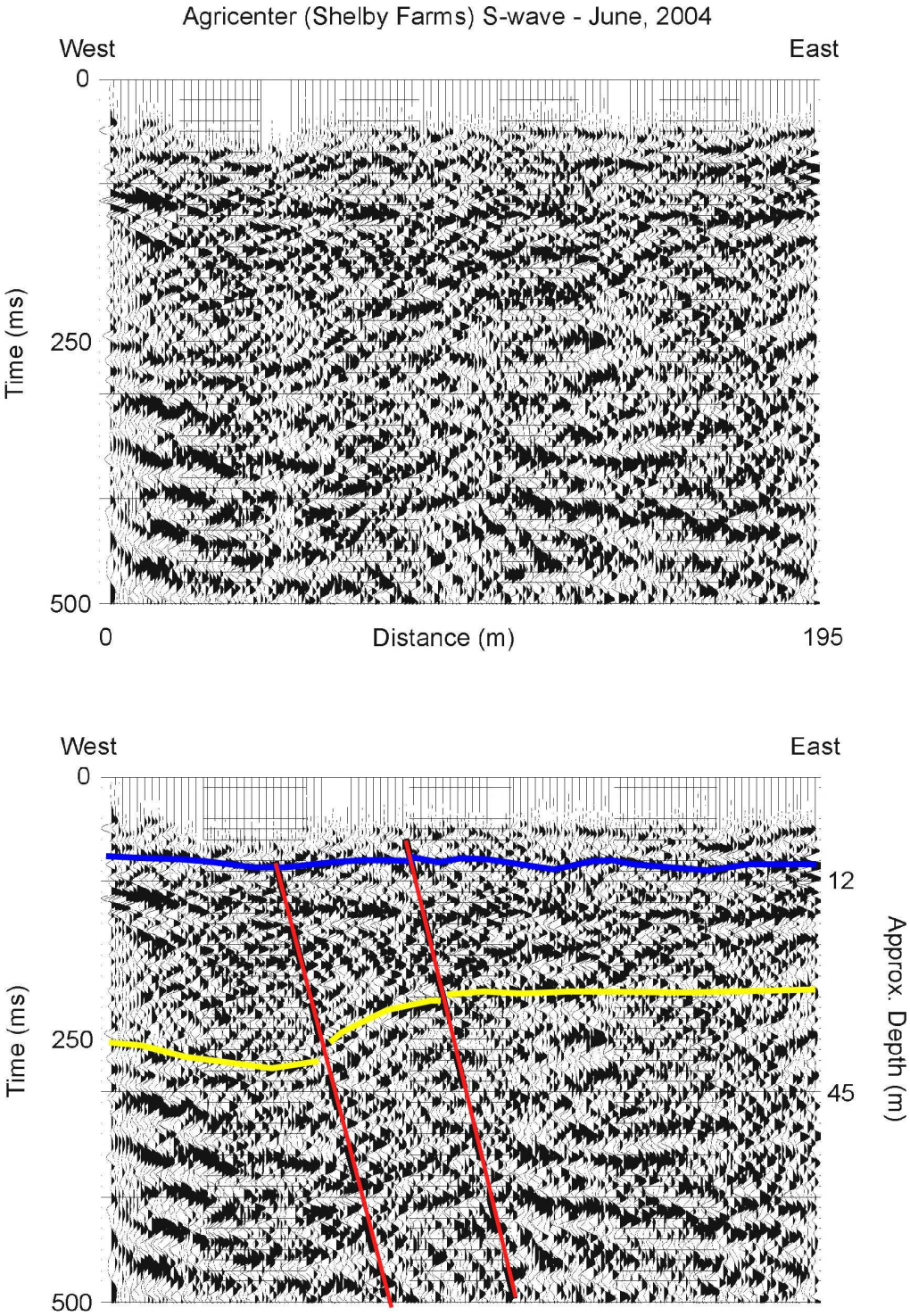

Figure 11. Moore_S shallow S-wave seismic reflection profile. The blue highlighted reflector is the top of the Upper Claiborne Group and the yellow is the top of the Lower Claiborne Group. Two faults bound a tilted portion of the Lower Claiborne Group. This down-to-the-west step corresponds with the up-section projection of the fault in the Moore_P profile (Figure 10). See Figure 9 for profile location.

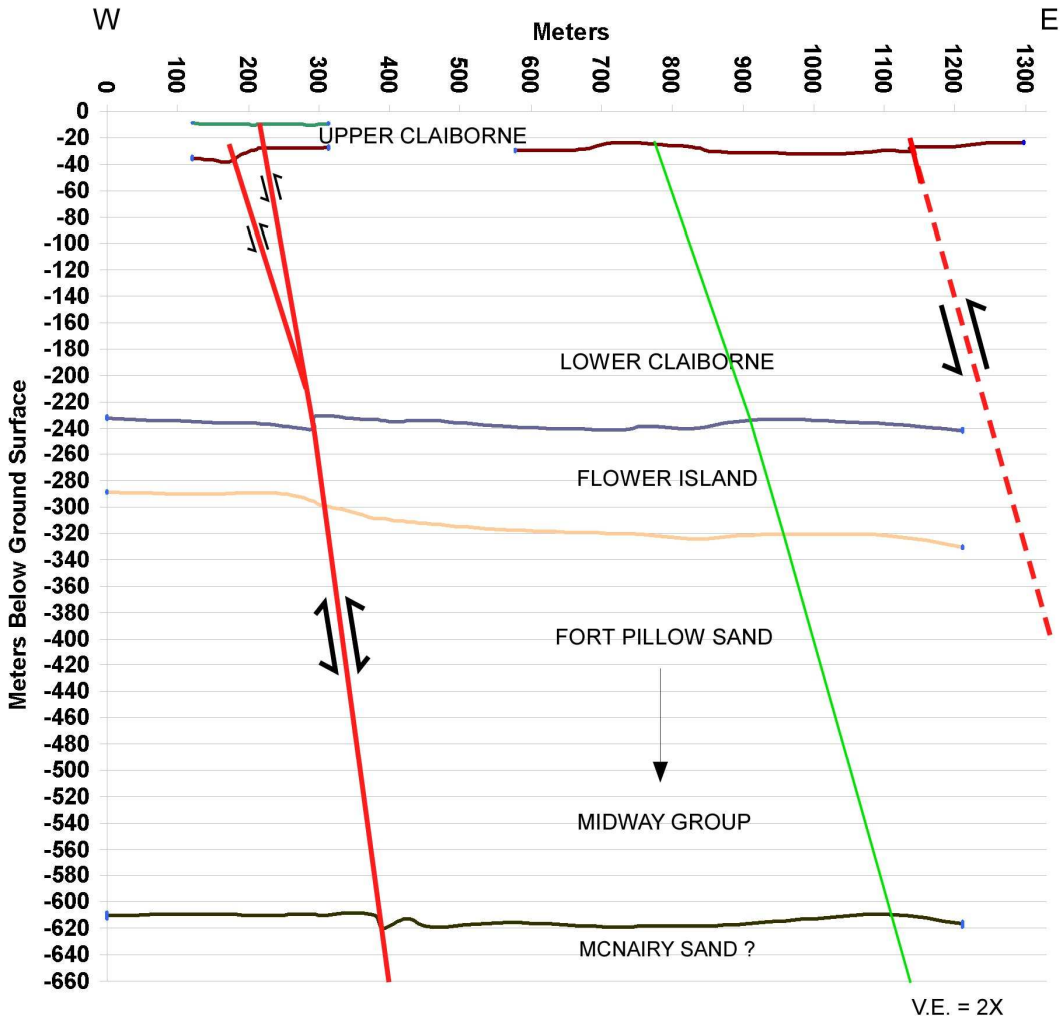

Figure 12. Composite geologic cross-section of the Moore_P, Moore_S, and Shelby01 seismic reflection profiles. The western fault is the Ellendale Fault and the eastern one is the Shelby Farms Fault. The green line is an anticlinal axis. Cross section corresponds with Figure 10.

not appear to continue up-section through the Upland Complex.

Depth Converted Geologic Cross-Section of the James_S Profile

To provide a more accurate rendition of the stratigraphy and the faults, a depth converted geologic cross-section of the James_S profile was constructed (Fig. 22). There are two faults within the Hollywood Fault zone that have apparent dips of 25°E (estimated true dips of 28°E). The western fault has 1.5 m of down-to-the-west reverse displacement at

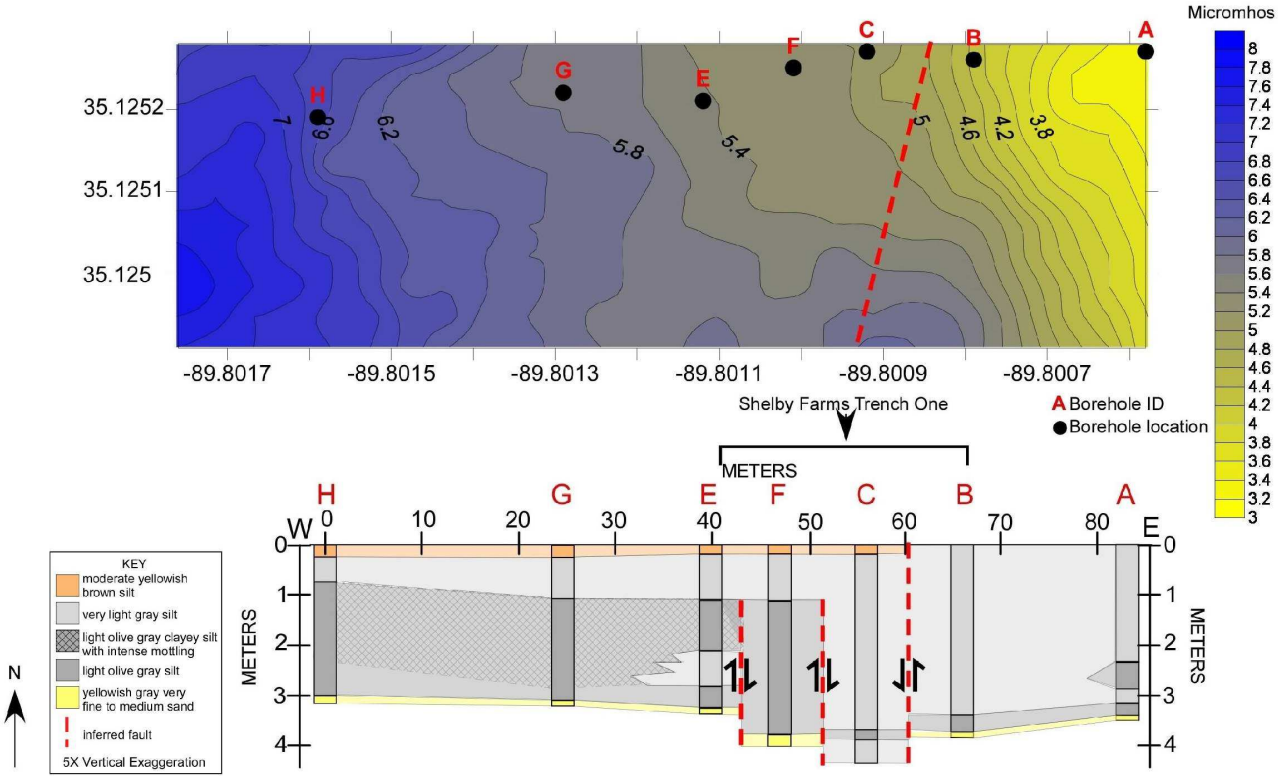

Figure 13. Electrical conductivity survey acquired south of Moore Road to investigate the Shelby Farms Fault (red dashed line). Boreholes are the labeled black dots on the map and the columns in the geologic cross section below. Displacements are interpreted between boreholes E and B. The conductivity survey is located in the southern blue box across the Shelby Farms Fault on Figure 9.

the top of the Lower and Upper Claiborne groups and 0.7 m at the top of the Upland Complex. The eastern fault has 1.8 m of down-to-the-west displacement at the top of the Lower and Upper Claiborne groups and does not displace the Upland Complex.

Electrical Conductivity Survey

For the purpose of gaining additional near surface information about the Hollywood Fault zone an electrical conductivity survey was acquired to the south of the location where the western fault projected to the surface (Figs. 20 and 23). Within the electrical conductivity survey a N25^{o}E trending anomaly was observed with low conductivity on the east and higher conductivity to the west. Therefore, the conductivity survey suggests a near-surface displacement along the western fault in the Hollywood Fault zone.

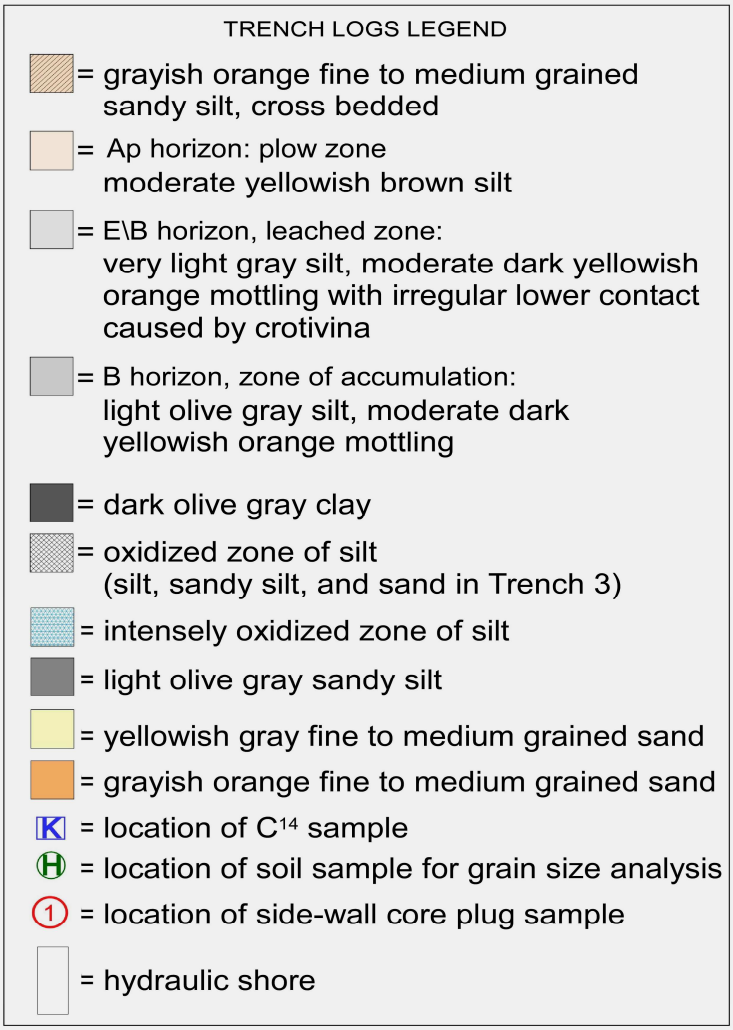

Figure 14. Legend for Trenches One, Two, and Three.

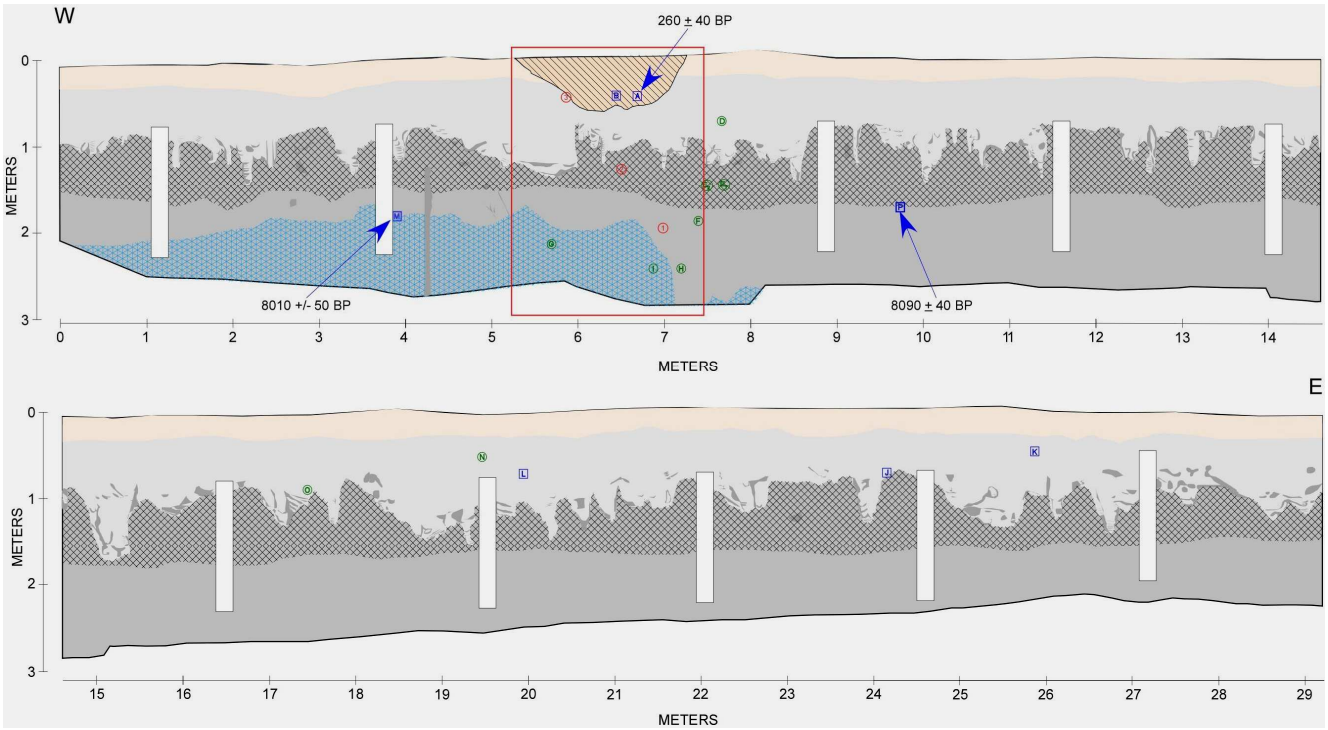

Figure 15. Shelby Farms Trench One located in Figure 13. The southern wall was logged then flipped for easier comparison with the seismic reflection profiles, electrical conductivity surveys, and shallow borehole transect. See Figure 14 for unit and symbol descriptions. A possible fault is inside the red box.

Conclusions

Subsurface stratigraphic mapping conducted in this research substantiated the shallow northeast trending down-to-the-west faults previously identified by Velasco et al. (2005), but also identified east trending down-to-the-north linking faults. A seismic reflection line acquired across the Ellendale Fault reveals that at depth it is a down-to-the-east normal fault. However, at shallow depth the Ellendale Fault is a down-to-the-west reverse fault and has therefore undergone tectonic inversion. The Lower Claiborne Group surface has the largest displacements and the greatest number of faults indicating fault reactivation through time.

Shelby Farms Trench One, excavated across the projected trend of the Shelby Farms fault, exposed a portion of the trench where a surface channel was cut above a subtle stratigraphic change in the base of the trench. Analyses of side-wall-core plugs for shear fabric revealed no evidence of faulting. However, the lack of shearing evidence may be the result of the fine-grained sediments not being able to preserve evidence of shear movement or due to the strong pedogenic overprint.

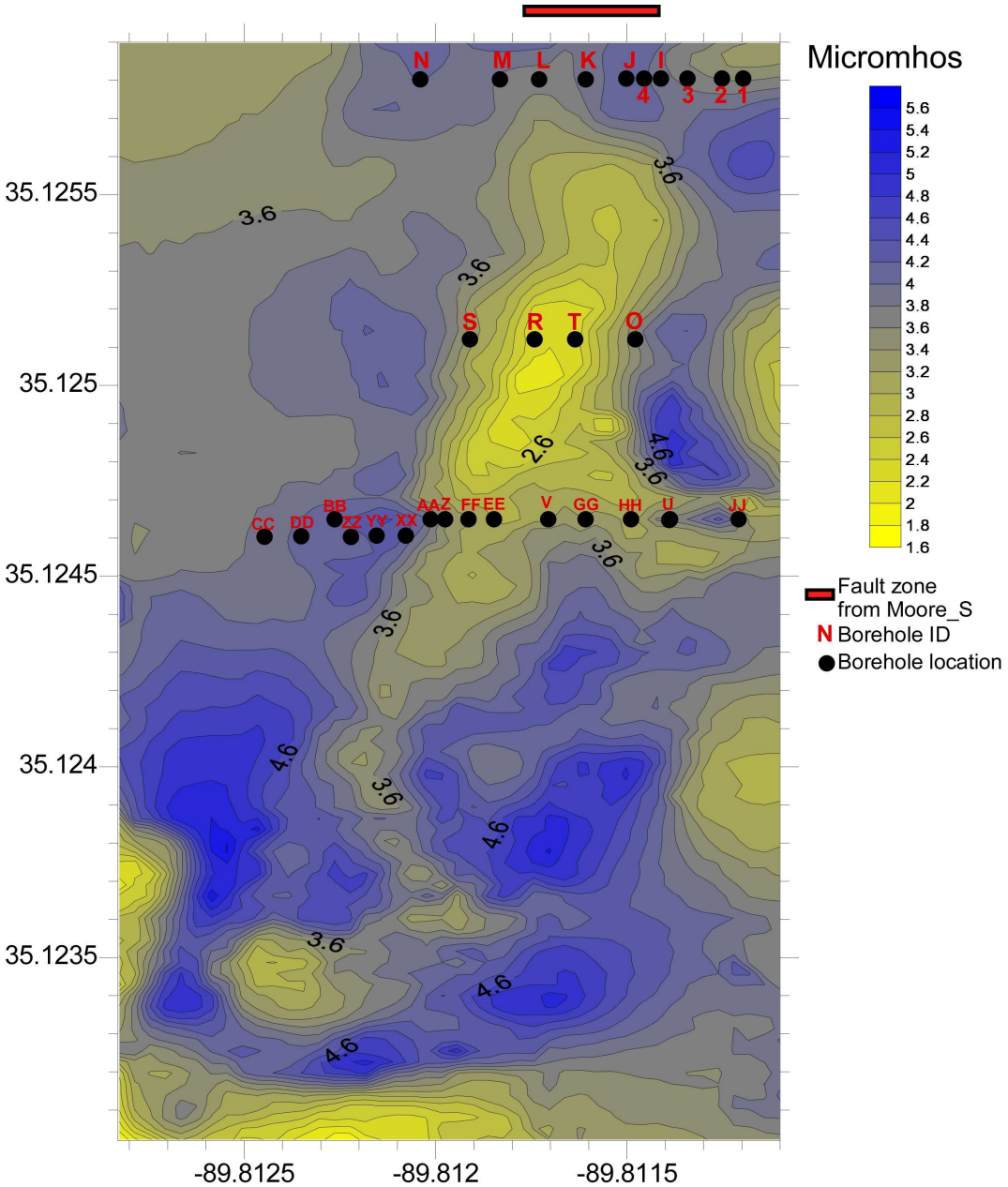

Figure 16. Electrical conductivity survey south of the Ellendale Fault zone (red bar at the top). An anomaly of low conductivity that trends to the northeast aligns with the Ellendale Fault zone's projected location. Boreholes are labeled black dots. Survey is located in the blue box across the Ellendale Fault of Figure 9.

Trenches excavated across the projected Ellendale fault (Shelby Farms Trench Two and Three) indicated that no Holocene movement has occurred, but did reveal minor earthquake induced liquefaction deposits. A more definitive answer as to whether Holocene faulting has occurred on this fault could be provided by linking Trenches Two and Three, which would cross the entire fault zone and conductivity lineament.

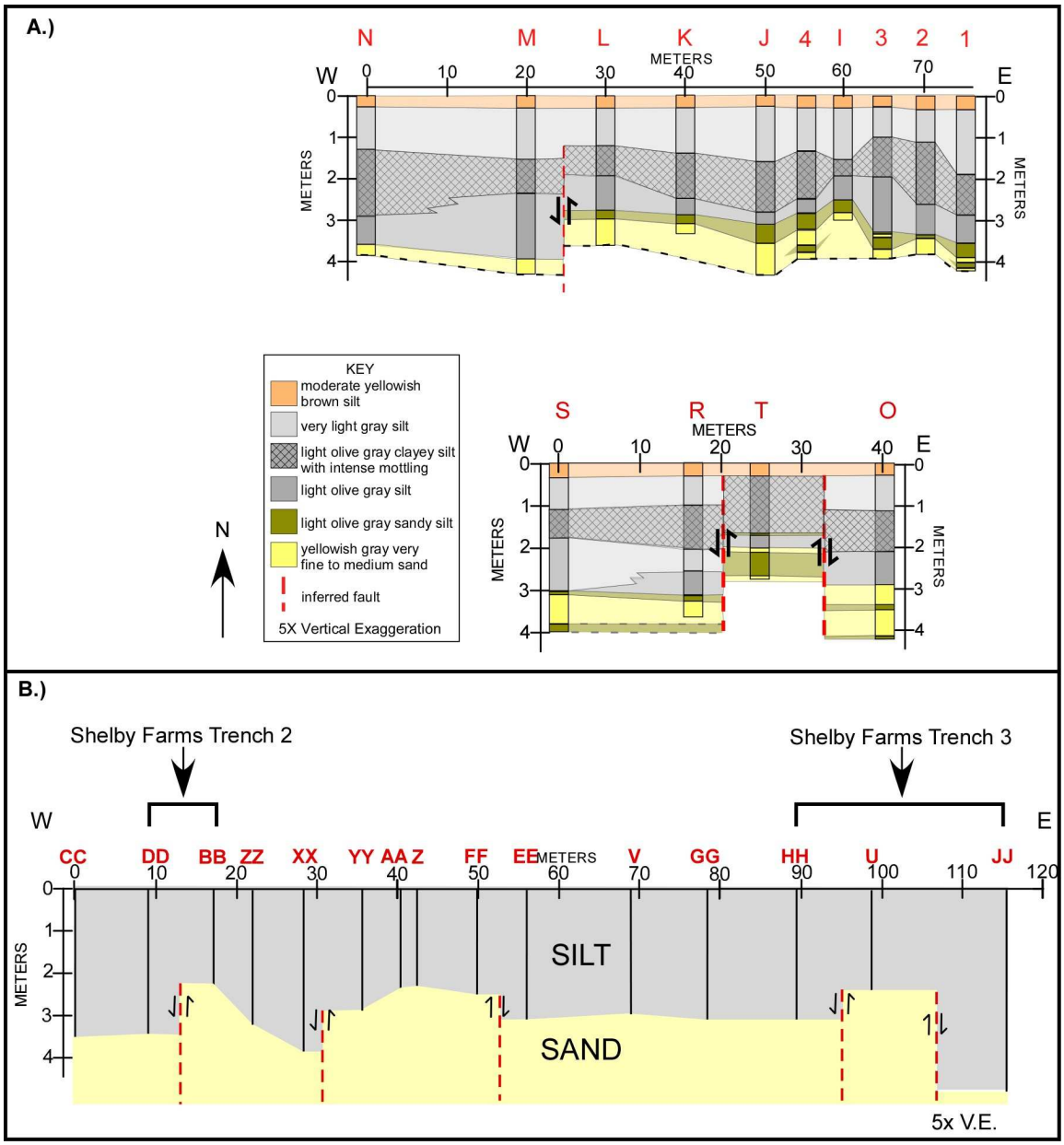

Figure 17. Borehole transects acquired across the electrical conductivity anomalies and the projected trend of the Ellendale Fault. A) Displacements were interpreted between boreholes M, L, R, T, and O respectively. B) Auger-hole transect across the electrical conductivity anomalies and the projected trend of the Ellendale Fault. Displacements were interpreted between DD, BB, FF, EE, HH, U, and JJ respectively. The locations of Shelby Farms Trenches Two and Three are labeled above the auger-hole transect. These bore holes are located in Figure 16.

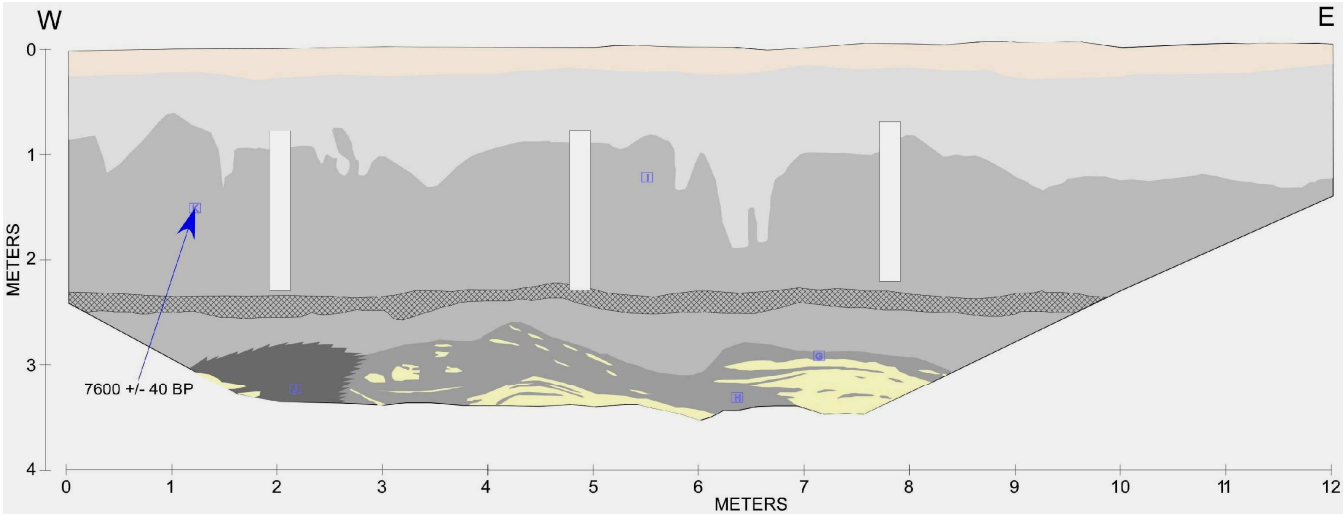

Figure 18. Shelby Farms Trench Two. The southern wall was logged then reversed to represent the north wall of the trench for easier comparison with the seismic reflection profiles, electrical conductivity surveys, and shallow borehole transect. See Figure 17 for location and Figure 14 for unit and symbol descriptions.

The Hollywood Fault zone in the James Road study area is composed of two east-dipping thrust faults. The western most fault displaces the Pliocene Upland Complex ~ 0.7 m and has an estimated trend of N25^{o}E based on the anomaly present in the electrical conductivity survey conducted immediately south of the seismic survey. The Hollywood fault zone is likely associated with the larger Memphis fault that is located to the west of the James Road study area. To better understand any association between the Hollywood Fault zone and the Memphis Fault, a deeper seismic line needs to be acquired further to the west that overlaps with the James_S profile.

This study utilized Shelby County geologic and geophysical data to constrain locations of faults that displace the Lower Claiborne Group (Memphis Sand) through the Upland Complex. The Memphis Sand is Shelby County's aquifer. Thus, these faults are not only potential seismic hazards but may influence groundwater flow beneath Shelby County.

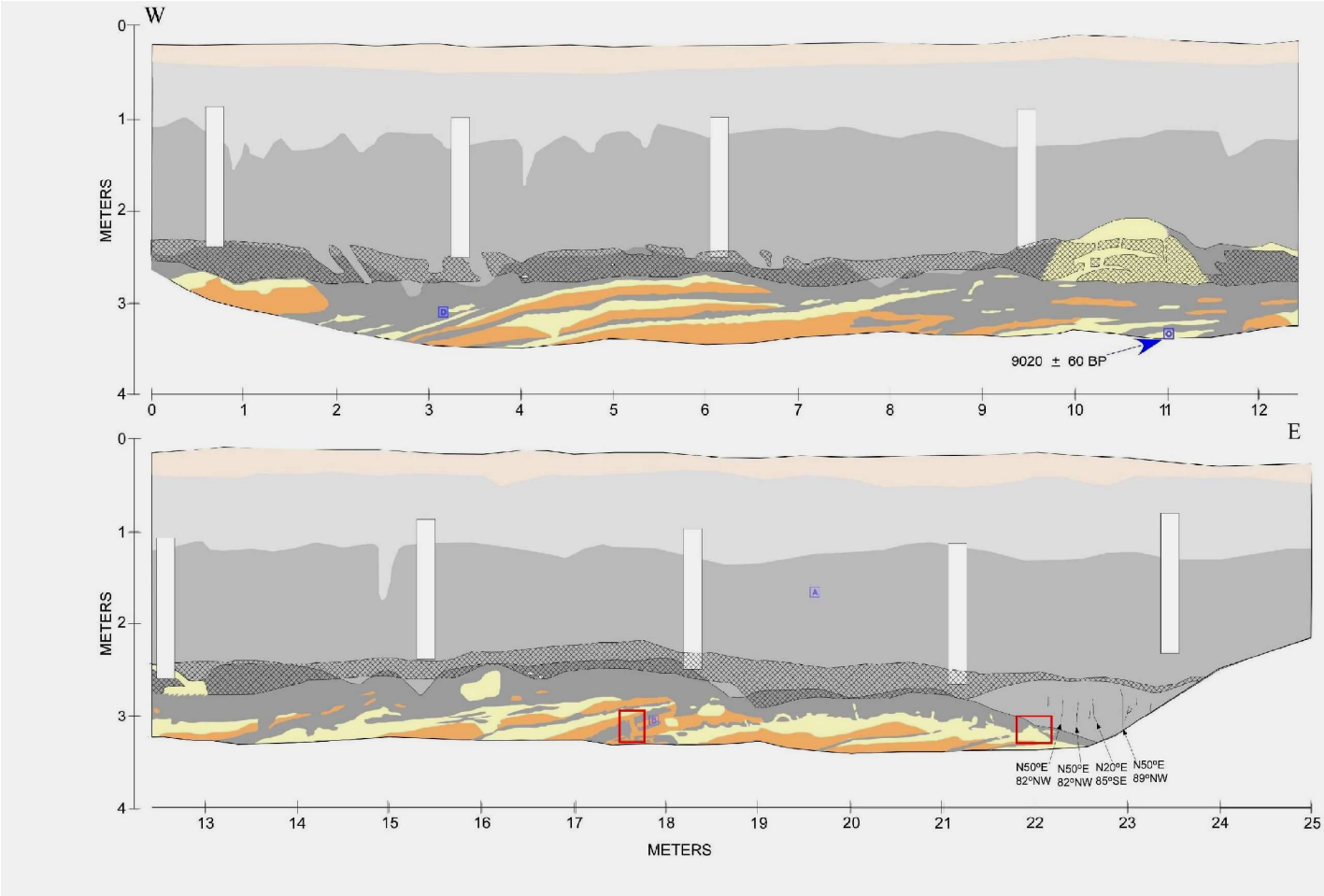

Figure 19. Shelby Farms Trench Log Three. The southern wall was logged then reversed to represent the north wall of the trench, for easier comparison with the seismic reflection profiles, electrical conductivity surveys, and shallow borehole transect. The trench is located in Figure 17 and the descriptions of each unit and symbol can be found in Figure 14. At the base of the trench point bar deposits are present as the result of the meandering ancestral Wolf River. Fractures and their orientations are between meter 22 and 23. The Red boxes outline areas where minor earthquake induced liquefaction features were observed.

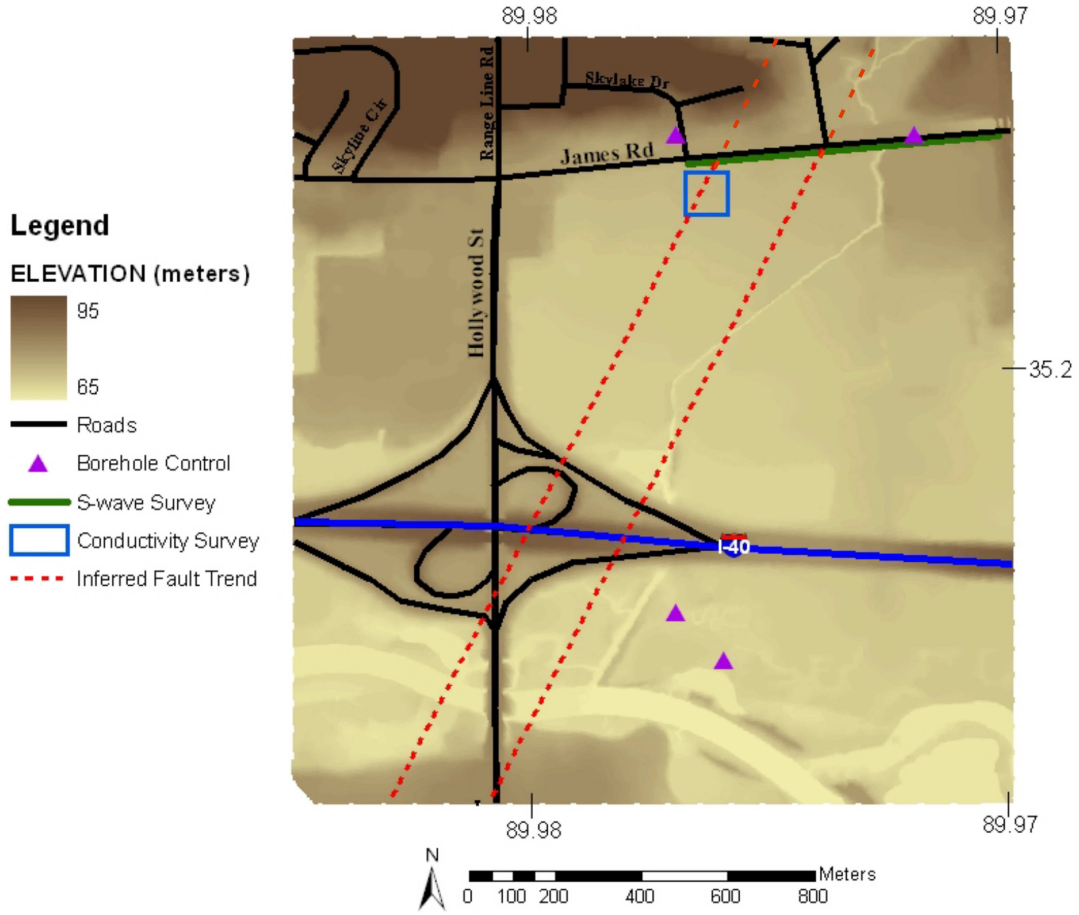

Figure 20. James Road study area. Area of blue box located in Figure 3.

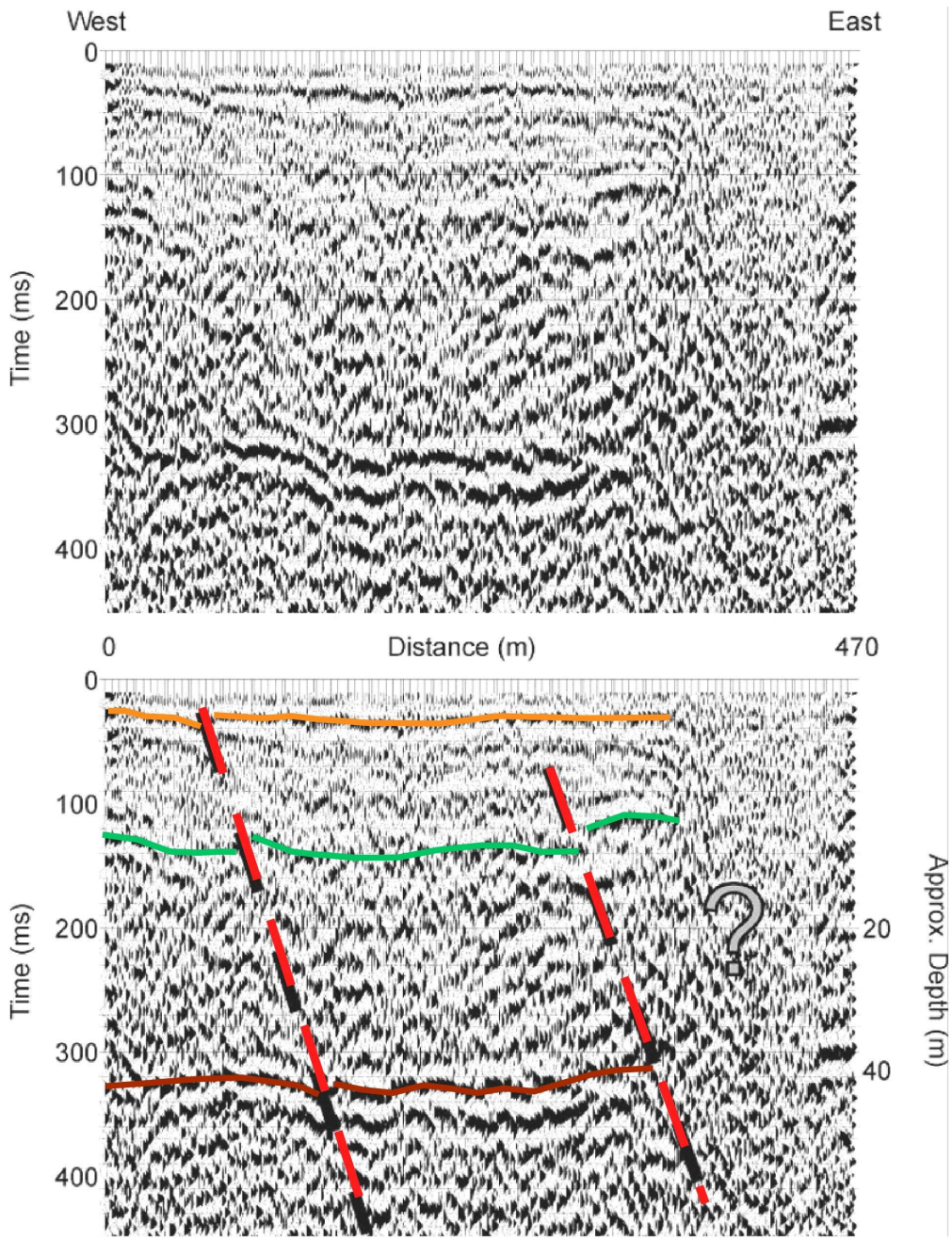

Figure 21. James_S shallow S-wave profile. The reddish brown highlighted reflector is ~ 40 m below the surface and is the top of the Lower Claiborne. The green highlighted reflector is ~ 14 m below the surface and is top of the Upper Claiborne. The orange highlighted reflector is ~3.5 m below the surface and is the top of the Upland Complex. Two down-to-the-west faults are imaged. The western most fault displaces the strata through the Upland Complex and the eastern fault displaces the strata up through the Upper Claiborne. The location of the profile can be observed in Figure 20.

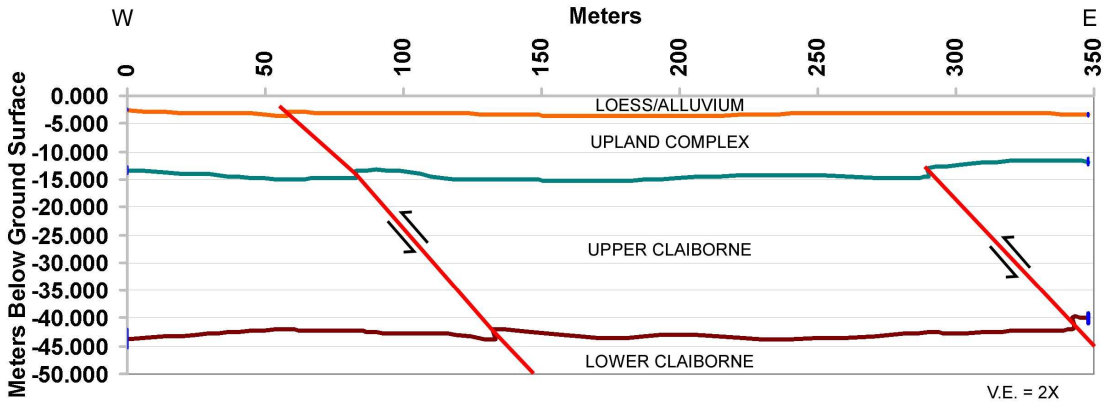

Figure 22. Depth converted geologic cross-section of the James_S profile (Fig. 21).

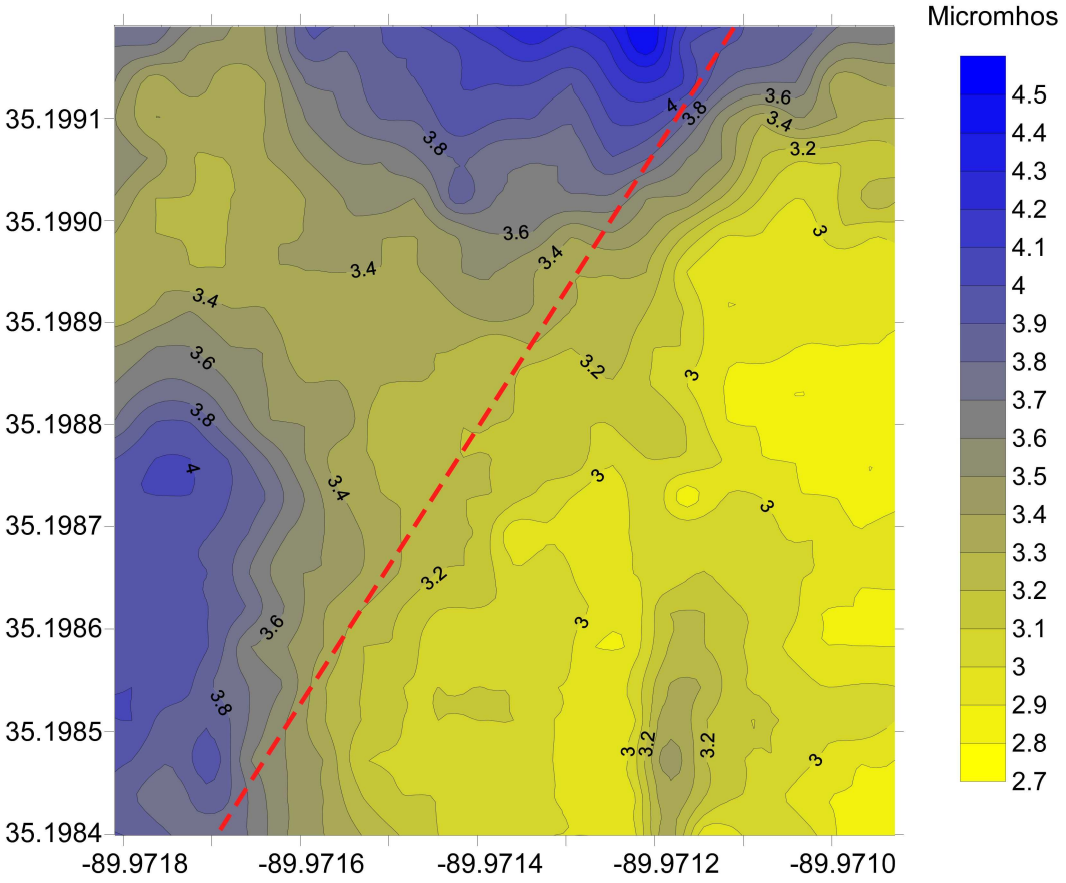

Figure 23. Electrical conductivity survey in the James Road study area. A N25°E trending anomaly (red dashed line) that has been interpreted to represent the western most fault imaged in James_S (Fig. 21). See Figure 20 for location of the electrical conductivity survey.

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