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Geologic Mapping of Lake County, Tennessee

Taylor Weathers

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GEOLOGIC MAPPING OF LAKE COUNTY, TENNESSEE

by

Taylor Weathers

A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

Major: Earth Sciences

The University of Memphis

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ABSTRACT

Lidar data, lignite boring logs, water well logs, petroleum exploration logs, geotechnical logs, and previously interpreted seismic reflection lines were used to map the stratigraphy and structure beneath Lake County, Tennessee. Structure contour maps were made of the tops of the Paleozoic, Cretaceous, and Eocene. Isopach maps were made of the Cretaceous, Paleogene, and Quaternary sections. A 3-dimensional lithologic model was constructed to illustrate the Quaternary alluvial facies of Lake County in five-foot thick layers. Additionally, a 3-D geological model was built for Lake County, which shows the stratigraphy and structure from the Quaternary to the Paleozoic. Cross sections were also created to illustrate the subsurface geology. The maps and cross sections reveal Quaternary faulting on the Reelfoot, Axial, Tiptonville dome backthrust, Cottonwood Grove, and Ridgely faults.
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1. INTRODUCTION

1.1 Significance and Purpose

The New Madrid seismic zone (NMSZ) in the central Mississippi River valley is known for its historically devastating earthquakes of 1811-1812 and its continued seismicity (Fig. 1) (Penick, 1981; Csontos and Van Arsdale, 2008). This project was initiated to map the surface and subsurface geology of Lake County, Tennessee (Fig. 2). The geologic surface and subsurface maps generated in this research will contribute to the development of seismic hazard maps and liquefaction potential maps by seismologists and engineers that will be created to better predict ground motion and damage in Lake County in the event of future NMSZ earthquakes. This project is funded by a Housing and Urban Development (HUD) grant and is part of a five-year multidisciplinary project, entitled the University of Memphis Hazard Mapping, Assessment and Education (HazMAE) project, which will provide multi-hazard data to communities for hazard mitigation and resilience efforts.

1.2 Geography and Hazards of Lake County

Lake County (Fig. 2) is a small, rural county located in northwestern Tennessee. Its geographical boundaries include the Mississippi River on the west and the Running Reelfoot Bayou on the east. It is bordered by several counties including both Dyer and Obion counties in Tennessee on the south and east, both Pemiscot and New Madrid counties in Missouri on the west, and Fulton County, Kentucky on the north. The entire county is located within the Mississippi River floodplain west of the Mississippi River bluffs. Lake County overlies the northwest-striking Reelfoot reverse fault that was responsible for the February 7, 1812 New Madrid earthquake and the northeast-striking, right-lateral strike-slip Axial fault (Johnston and
Figure 1. The northern Mississippi embayment (purple line), Reelfoot rift with bounding faults (black lines), and New Madrid seismic zone. Earthquake epicenters (CERI Earthquake Catalog 1974-2006) are shown as small colored circles (Csontos and Van Arsdale, 2008). The southern star near Blytheville, Arkansas is an estimate of the epicenter of the December 16, 1811 M 7.5 earthquake, the northern star is an estimated epicentral location of the January 23, 1812 M 7.3 earthquake near New Madrid, Missouri, and the middle star is an estimated epicentral location of the February 7, 1812 M 7.7 earthquake near the town of Tiptonville, Tennessee (Johnston and Schweig, 1996; Cramer and Boyd, 2014) (from Van Arsdale, 2009).
Figure 2. Digital Elevation Map (DEM) of West Tennessee and a portion of the central Mississippi River valley. Counties are labeled. The red outline locates the project area and a more detailed DEM of Lake County, TN is provided in the inset box. Included in the Lake County inset map are the towns (black dots) of Tiptonville (T) and Ridgely (R) and Reelfoot Lake (RFL). The yellow box within the inset map shows the location of Figure 4.
Schweig, 1996). Uplift of the Reelfoot fault and coincident subsidence of the Reelfoot Lake basin was responsible for the creation of Reelfoot Lake by the temporary damming and permanent local ponding of the Running Reelfoot River. Over a larger area, the Tiptonville dome and Ridgely ridge were uplifted as part of the Lake County uplift (LCU) (Fig. 3) (Russ, 1982; Purser, 1996; Purser and Van Arsdale, 1998; Van Arsdale et al., 1998; Van Arsdale, 2009). Seismicity is ongoing, and with newer technology, geologists, seismologists, and engineers have a greater ability to understand these threats and a way to map once enigmatic structures in the subsurface. The threat of future earthquake ground shaking and liquefaction remains an ever-present concern for the county. Large areas of the region are covered by sand blow deposits due to 1811-1812 earthquake liquefaction. The sand blow deposits overlie Mississippi River floodplain overbank silt and clay sediments. Figure 4 shows an area of Lake County and the town of Ridgely with many sand blow deposits (white patches) southeast of Ridgely on the Mississippi River floodplain. The liquefaction occurs as small circular mounds of sand or as linear fissure sand deposits on the landscape. The towns of Ridgely and Tiptonville have little evidence of liquefaction and this is likely due to urbanization after the New Madrid earthquakes of 1811-1812.
Figure 3. Map of the major faults and structures of Lake County area. This includes the Lake County uplift (black line) and its proposed west-bounding backthrust (dashed, BT-2), the northwest-trending Tiptonville dome and its proposed west-bounding backthrust (dashed, BT-1), and the east-facing Reelfoot scarp monocline (RS) along the Reelfoot reverse fault, which bounds the Tiptonville dome and locally the Reelfoot Lake (RL). Also shown is the southwest-trending Ridgely ridge bounded on the west by the Cottonwood Grove fault (CGFZ) and on the east by the Ridgely fault (RFZ). Axial fault (AF) is shown. New Markham fault (NMF) interpreted by Guo et al. (2014) (red dashed-line) and original interpretation by Odum et al. (1994, 1998) and Van Arsdale et al. (1998) (blue dashed-line) (modified from Purser and Van Arsdale, 1998).
Figure 4. Aerial photograph (1957) from the US Army Corps of Engineers (USACE) showing extensive liquefaction features including light-toned sand blows and linear fissures on the landscape near Ridgely, TN.
1.3 New Madrid Seismic Zone and its Earthquakes

The NMSZ is an intraplate seismic zone located in the central Mississippi River valley (Figs. 1 and 5). The NMSZ is responsible for the three ≥ M 7.3 New Madrid earthquakes of 1811-1812 that violently shook the region affecting an area all the way to the East Coast of the United States (Fuller, 1912; Johnston and Schweig, 1996; Van Arsdale, 2009; Cramer and Boyd, 2014). The December 16, 1811 ~M 7.5 earthquake occurred on the northeast-striking, dextral strike-slip Axial fault (AF) near the present-day city of Blytheville, Arkansas (Johnston and Schweig, 1996). The January 23, 1812 ~M 7.3 earthquake occurred on the northeast-striking, dextral strike-slip New Madrid North fault (NMNF) near the town of New Madrid, Missouri. The February 7, 1812 ~M 7.7 earthquake occurred on the northwest-striking Reelfoot reverse fault near the present-day town of Tiptonville, Tennessee (Cramer and Boyd, 2014). In 1811-1812 few people lived in the region, but contemporary journal entries, newspapers, and eyewitness accounts speak of an unimaginable landscape like that of a horror story (Penick, 1981). Sand blows and fissures tore up the landscape, with some sand blows ejecting sand possibly 100 ft. high like geysers and releasing a sulphurous odor, river banks collapsed, landslides occurred along the eastern Mississippi River bluffs, and houses were damaged or destroyed (Penick, 1981; Van Arsdale, 2009). Similar conditions today would cause catastrophic damage and major loss of life in the central United States. Agriculture could suffer due to sand blow deposition, buildings could collapse or become uninhabitable, and major highways and bridges would be damaged making aid access and transportation difficult.
Figure 5. Earthquake epicenters from 1974 to 2017 of the NMSZ (CERI Earthquake Catalog 1974-2017). Major faults are illustrated with bold black lines and labeled: NRF – Reelfoot North fault, SRF – Reelfoot South fault, AF – Axial fault, NMNF – New Madrid North fault, and NMWF – New Madrid West fault aka Risco fault. Cities are shown as black square and labeled: B – Blytheville, AR, M – Memphis, TN, J – Jackson, TN, D – Dyersburg, TN.
1.4 Seismic Hazards Analysis

Seismic hazard maps and liquefaction potential maps have been made for Shelby County, TN and the city of Memphis (Broughton et al., 2001; Cramer et al., 2004, 2014 and 2018; Cramer, 2006; Rix and Romero-Huddock, 2006; Van Arsdale et al., 2012), southeastern Missouri (Chung and Rogers, 2015), and on a smaller scale the central Mississippi River valley (CMRV) (Obermeier, 1988). Soil, surface and subsurface geology, and subsurface structure data were required for the development of these maps. Seismic velocity models have been developed for the region by Langston and Horton (2014), Cramer and Boyd (2014), Ramirez-Guzman et al. (2015), and Boyd et al. (2015). The geologic, geotechnical, and seismological maps are integrated into seismic hazard maps, which provide an estimate of expected ground motion and liquefaction in the event of an earthquake of a particular size. These data also are used for creating earthquake early warning systems. Interval velocities of the geologic units within the uppermost 300 m of the Mississippi embayment dampen the amplification of peak ground acceleration (PGA) in the Mississippi River floodplain due to nonlinear soil behavior but amplify PGA in the uplands due to soil resonance and more linear soil behavior (Dhar and Cramer, 2017). Shear-wave velocity ($V_s$, m/s) increases with depth in the Mississippi embayment, but there is nonlinear variation of $V_s$ due to local geological influences such as sediment thickness, depth (or elevation) of deposit, age, and type of sediment or bedrock. The Quaternary-Cretaceous unconsolidated sediments of the Mississippi embayment possess lower $V_s$ values than the underlying Paleozoic bedrock (Table 1) (Dhar, 2017; Dhar and Cramer, 2017). Calculating ground motion and developing seismic hazard models requires the use of geological unit thickness, depth, and unconsolidated sediment or bedrock type (Dhar, 2017). Thus, a 3D
geological model is required so that seismic hazard models can incorporate local geological effects.

The New Madrid earthquakes of 1811-1812 caused severe regional liquefaction. However, there is also evidence for earlier liquefaction events from prehistoric earthquakes occurring within the NMSZ and the CMRV revealed in trenching, geomorphic analysis, and geophysical techniques (Saucier, 1987, 1994; Obermeier, 1988, 1989; Rodbell and Bradley, 1993; Rodbell, 1996; Tuttle et al., 1999, 2002, and 2005; Wolf et al., 2006). Thus, liquefaction potential is a major concern in the Mississippi River floodplain and its major tributaries. Important factors that control liquefaction are: 1) ground-motion, 2) water table depth, 3) near-surface sediment age, and 4) near-surface geology (Dhar, 2017; Dhar and Cramer, 2017). Liquefaction potential index (LPI) maps require all four sets of data. Dhar and Cramer (2017) developed probabilistic and deterministic liquefaction hazard maps for the Mississippi embayment and note that the Quaternary deposits in the eastern lowlands have the highest chances of experiencing widespread liquefaction if another $\geq M 7.0$ earthquake occurs in the future. No detailed, county-scale earthquake hazard map has been produced for Lake County, TN, and the NMSZ remains a significant threat to the region.
Table 1. Shear-wave velocities ($V_s$) of the various formations from Gomberg et al. (2003), Cramer et al. (2004), and Cramer (2006), Dhar (2017) and Dhar and Cramer (2017).

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<th>$V_s$ (m/s)</th>
<th>Source</th>
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<td>Floodplain Sediments</td>
<td>171 ± 24</td>
<td>Gomberg et al. (2003)</td>
</tr>
<tr>
<td>Loess</td>
<td>192 ± 37</td>
<td>Estimated from a 420-m MLGW well log and 900-m Wilson 2 oil and gas exploration well; Cramer et al. (2004); Cramer (2006)</td>
</tr>
<tr>
<td>Upland Complex</td>
<td>268 ± 72</td>
<td></td>
</tr>
<tr>
<td>Jackson, Cockfield, and Cook Mtn. (Upper Claiborne Group)</td>
<td>413 ± 105</td>
<td></td>
</tr>
<tr>
<td>Memphis Sand</td>
<td>530 ± 134</td>
<td></td>
</tr>
<tr>
<td>Flour Island</td>
<td>675 ± 100</td>
<td></td>
</tr>
<tr>
<td>Fort Pillow</td>
<td>775 ± 50</td>
<td></td>
</tr>
<tr>
<td>Old Breastworks and Midway Group</td>
<td>850 ± 50</td>
<td></td>
</tr>
<tr>
<td>Cretaceous</td>
<td>1175 ± 125</td>
<td></td>
</tr>
<tr>
<td>Paleozoic</td>
<td>2800</td>
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2. GEOLOGIC HISTORY

2.1 Stratigraphy, Structure, and Geological History of the Central Mississippi River Valley

To understand the present-day seismicity in the NMSZ, an understanding of the regional geology in the CMRV is needed (Fig. 6). Figure 7 shows a general stratigraphic column for western TN, which can be applied to the study area. Precambrian crystalline basement rock of the Eastern Granite-Rhyolite Province (1.47 Ga) underlies the present-day region of the CMRV (Van Schmus et al., 2007; Van Arsdale, 2009). The upper mantle in the region contains a significant low-velocity zone at approximately 200 km depth, which may act as a viscous weak zone able to transfer tectonic stress from the upper mantle to seismogenic faults within the upper crust (Chen et al., 2014). The N45ºE – striking Reelfoot rift is a failed Cambrian rift system, an aulocagen, which formed within the crystalline basement during the breakup of the Neoproterozoic supercontinent Rodinia (Fig. 8) (Hildenbrand et al., 1982, 1985; Dart and Swolfs, 1998; Csontos et al., 2008; Van Arsdale, 2009; Martin and Van Arsdale, 2017). The Reelfoot rift is situated within the Precambrian Eastern Granite-Rhyolite Province and is responsible for seismicity within the CMRV. The rift is comprised of Cambrian normal faults that have been reactivated as predominantly northeast-striking, right-lateral strike-slip faults, northwest-southeast – striking reverse faults with local east-west compression (stepover zones) (Csontos et al., 2008; Van Arsdale and Cupples, 2013), and by east-west normal faults with local north-south extension manifested as structural grabens (Van Arsdale and Cupples, 2013; Martin and Van Arsdale, 2017).

Paleozoic rocks of the Lower to Upper Cambrian include those of the Potsdam Megagroup and are differentiated into the basal Lamotte sandstone, the Bonneterre dolomite, and the Elvin shale (Fig. 7) (Howe and Thompson, 1984; McKeown et al., 1990). Paleozoic rocks of
Upper Cambrian to Lower Ordovician age of the undifferentiated Knox Megagroup immediately overlie the Potsdam Megagroup (Howe and Thompson, 1984; Howe, 1985; McKeown et al., 1990; Nelson and Zhang, 1991; Lumsden and Caudle, 2001; Van Arsdale, 2009). The Paleozoic deposits mainly consist of shallow-marine carbonates and nearshore clastics deposited in warm, shallow seas during the Sauk transgression. Attempts to map some of the formations in the Knox Megagroup in the area have been successful in the NMSZ (Csontos, 2007). The Appalachian-Ouachita orogenic belt (Fig. 9) (Cushing et al., 1964; Thomas, 1988, 1989, and 2006; Cox and Van Arsdale, 1997, 2002; Van Arsdale and Cox, 2007; Van Arsdale, 2009) has extended from Oklahoma to Alabama since the formation of Pangea during the Paleozoic. Within the Mississippi River valley, the Appalachian-Ouachita orogenic belt was subsequently eroded during the Middle Cretaceous when the North American plate drifted over the Bermuda hotspot (Figs. 10 and 11) (Cox and Van Arsdale, 1997, 2002; Van Arsdale and Cox, 2007; Csontos et al., 2008; Van Arsdale, 2009). Thermal uplift by the Bermuda hotspot caused the rejuvenation of the Reelfoot rift basement faults, the intrusion of plutons and the uplift, subsidence, and erosion of the Appalachian-Ouachita orogenic belt. The mid-Cretaceous uplift lead to the development of the Middle Cretaceous unconformity and Late Cretaceous subsidence resulted in the inundation of the landscape by the Gulf of Mexico to form the Mississippi embayment (Fig. 11). This is also interpreted to have changed the course of the ancient Mississippi River from north-flowing to south-flowing (Cox and Van Arsdale, 2002).
Figure 6. The Mississippi embayment in the central Mississippi River valley. Orange color denotes Precambrian rock, blue and purple colors are Paleozoic rocks, and green, yellow, and gray colors are Late Cretaceous and younger sediments. Cities represented by red initials include: C–Cairo, Illinois; M–Memphis, Tennessee; BR–Baton Rouge, Louisiana; LR–Little Rock, Arkansas; and NO–New Orleans, Louisiana. Features represented by yellow initials include: A–Appalachian Mountains; O–Ouachita Mountains; OZ–Ozark Mountains; and ND–Nashville dome. CMRV is shown in box (from Van Arsdale, 2009).
Figure 7. Generalized stratigraphic column of West Tennessee. Quat. – Quaternary, Neo. – Neogene, EGRP – Eastern Granite-Rhyolite Province (modified from Parrish and Van Arsdale, 2004 and Ward, 2016).
Figure 8. Precambrian crystalline basement unconformity structure contour map with basement faults. Reelfoot rift extends from White River fault zone (WRFZ) past the Reelfoot fault (RF). Contour interval – 400 m elevation relative to mean sea level. Prominent fault structures (shown as black lines and initials) include: GRTZ–Grand River tectonic zone; CMTZ–Central Missouri tectonic zone; OFZ–Osceola fault zone; BMTZ–Bolivar-Mansfield tectonic zone; WRFZ–White River fault zone; EM–Eastern Rift Margin faults; AF–Axial fault; WM–Western Rift Margin fault; and RF–Reelfoot fault. The town of New Madrid (NM) and the city of Memphis are shown for reference (from Csontos et al., 2008).
Figure 9. Formation of Rodinia and the Grenville Mountains (~1 Ga) (from Thomas, 2006).
Figure 10. Track of the Bermuda hotspot (lower, yellow dashed-line) and the formation of the Mississippi embayment (white, dashed-line). Cambrian rift faults (yellow, curved-lines) exist beneath the Mississippi embayment (from Van Arsdale and Cox, 2007).
Figure 11. Bermuda hotspot (red) and the formation of the Mississippi embayment (from Van Arsdale and Cox, 2007).
The Mississippi embayment is a southwest-plunging erosional trough filled with Late Cretaceous through Cenozoic sediments within the CMRV with thickening of deposits along the axis of the trough (Fig. 12) (Cushing et al., 1964; Crone, 1981; Cox and Van Arsdale, 1997, 2002; Ward, 2016). From the Late Cretaceous to the Paleogene, the region was an area dominated by marine transgression and regression cycles. Late Cretaceous shallow-marine to fluvial-deltaic deposits, consisting of marls, chalk, clays, sands, and minor lignite, unconformably overlie the Paleozoic. These units include the Coffee Formation, Demopolis Formation, Coon Creek Formation, McNairy Sand, and Owl Creek Formation (Fig. 7) (Cushing et al., 1964; Crone, 1981; Van Arsdale and Tenbrink, 2000; Parrish and Van Arsdale, 2004; Van Arsdale, 2009; Martin and Van Arsdale, 2017). The Coffee Formation, Demopolis Formation, and Coon Creek Formations are thin or missing in the study area (Crone, 1981). This could be due to incomplete transgression of the Zuñi Sea (Lumsden et al., 2016) in the northern Mississippi embayment during this time, which could explain why the oldest of the Late Cretaceous deposits are missing in the New Madrid test well near New Madrid, Missouri.

Paleogene deep-marine to fluvial-lacustrine deposits overlie the Late Cretaceous deposits (Martin and Van Arsdale, 2017). Paleogene sediments make up a series of aquifers and aquitards in the northern Mississippi embayment. The best known aquifer is the Memphis Sand, also known as the Sparta Sand (Crone, 1981; Martin, 2008; Martin and Van Arsdale, 2017), which supplies drinking water to the region. The Paleogene units consist of the Paleocene Midway Group, the Eocene Wilcox and Claiborne Groups, and the Eocene-Oligocene Jackson Formation. The Midway Group contains the nearshore shallow-marine Clayton Formation and the overlying deep-marine Porters Creek Clay. The Clayton Formation is thin to missing in the northern Mississippi embayment, but thickens to the southwest (Cushing et al., 1964; Crone, 1981). The
Porters Creek Clay overlies the Late Cretaceous strata where the Clayton Formation is missing.
The overlying Wilcox Group contains predominantly nearshore shallow-marine sediments and includes the Old Breastworks Formation, the Fort Pillow Sand, and the Flour Island Formation. The Claiborne Group contains the fluvial Memphis Sand (Larsen and Brock, 2014; Martin and Van Arsdale, 2017), the lacustrine or shallow-marine Cook Mountain Formation (Martin, 2008; Van Arsdale, 2009), and the deltaic Cockfield Formation (Crone, 1981; Van Arsdale and Tenbrink, 2000; Martin, 2008; Martin and Van Arsdale, 2017). Locally, the Old Breastworks Formation is thin to missing. The Jackson Formation is interpreted to be a fluvial-lacustrine dominated deposit, yet may have served as the last major marine transgression in the northern Mississippi embayment (Fig. 13) (Cushing et al., 1964; Crone, 1981; Saucier, 1994; Van Arsdale and Tenbrink, 2000; Parrish and Van Arsdale, 2004; Van Arsdale and Cox, 2007; Van Arsdale, 2009). The Jackson Formation is locally exposed along the Mississippi River bluffs (Cushing et al., 1964), whereas its subsurface expression is poorly known due to erosional scouring by the Mississippi River and due to the inherent difficulty in differentiating the Jackson and Cockfield Formations (Crone, 1981). Crone (1981) suggests that the Cockfield Formation is mainly clay/silt dominated; whereas the Jackson Formation is sand dominant. Two other potential key factors in differentiating the Jackson and the Cockfield Formations could be to examine the fossil fauna, such as sporomorphs (spores/pollen), dinoflagellates, or forams present within each geologic unit and to determine if there are any significant changes in geophysical properties on geophysical logs when comparing the two formations (Crone, 1981; Frederiksen et al., 1982).

In western Tennessee, the Claiborne Group is faulted across the eastern margin of the Reelfoot rift, across rift outboard faults (Stevens, 2007; Martin, 2008; Martin and Van Arsdale, 2017), and by the NMSZ faults that also displace overlying Quaternary alluvium (Csontos et al.,
2008; Hao et al., 2013; Guo et al., 2014). The northern Mississippi embayment also contains the (~3.1 Ma) Pliocene Upland Complex (originally called the Lafayette Gravel by Potter 1955), which is a high-level fluvial terrace deposit of the ancestral Mississippi River system (Potter, 1955a, 1955b; Saucier, 1994; McCallister, 2004; Van Arsdale et al., 2007; Van Arsdale, 2009; Van Arsdale and Cupples, 2013; Cox et al., 2014; Cupples and Van Arsdale, 2014; Lumsden et al., 2016). The Upland Complex is composed of ferruginous sand and gravel containing only minor amounts of clay and silt (Van Arsdale et al., 2007; Lumsden et al., 2016). The Upland Complex does not occur within Lake County due to erosion by the Quaternary Mississippi River, but is found immediately to the east and is exposed within the Mississippi River bluffs (McCallister, 2004; Van Arsdale et al., 2007; Van Arsdale and Cupples, 2013; Cupples and Van Arsdale, 2014; Lumsden et al., 2016).

Quaternary deposits adjacent to Lake County include Pleistocene fluvial, lacustrine, and eolian deposits as well as Holocene fluvial deposits. Fluvial deposits of the Pleistocene consist primarily of braid belt terrace deposits (Fig. 14) (Saucier, 1994; Rittenour et al., 2007; Csontos et al., 2008; Cupples and Van Arsdale, 2014; Ward, 2016; Ward et al., 2017). Lacustrine deposits are locally found along the Mississippi River bluffs and Mississippi River tributaries (Saucier, 1987, 1994; Grimley et al., 2009). Pleistocene eolian deposits are loess units that accumulated primarily in the uplands of the Mississippi River. Loess is not found in Lake County as the landscape is Holocene, but loess is present just to the east in Obion County. Holocene sediments of the Mississippi River floodplain include overbank clay and silt, natural levee sand, crevasse splay sand and silt, point bar sand, and fluvial channel sandy gravel deposited by migrating meander scrolls (Cushing et al., 1964; Crone, 1981; Saucier, 1987, 1994; Guccione et al., 2002; Csontos and Van Arsdale, 2008; Csontos et al., 2008; Van Arsdale, 2009). Figure 15 shows a
generalized cross section of the Mississippi River floodplain in Lake County and adjacent upland in Obion County.

**Figure 12.** Cross section and oblique perspective of the Mississippi embayment sediments (beige, yellow, and green). C–Cairo, IL; NM–New Madrid, MO; M–Memphis, TN; CR–Crowley’s Ridge; WL–Western Lowlands; EL–Eastern Lowlands. Plutons (red) show Middle Cretaceous igneous intrusions along the Reelfoot rift formed by the Bermuda hotspot. Vertical exaggeration is approximately 45 (from Ward, 2016).
Figure 13. Map of subcrop and outcrop (pre-Wisconsin) in the central Mississippi River valley. Prominent Paleogene Mississippi River subcrops in the study area immediately underlying the Plio-Pleistocene unconformity are the Jackson and Cockfield (Claiborne Group) Formations (modified from Saucier, 1994).
**Figure 14.** Map showing Quaternary deposits throughout the CMRV. Several Pleistocene valley train terrace deposits are illustrated (Rittenour et al., 2007). Terraces: Ash Hill (24-27 Ka); Melville Ridge (34-41 Ka); Dudley (50-63 Ka); Si–Sikeston (18-20 Ka); Mh–Morehouse (12 Ka); P–Paragould (85 Ka); Bl–Blodgett (13 Ka); Ch–Charleston (14 Ka); T–Tertiary. Cities in bold: D–Dyersburg, TN; J–Jonesboro, AR; C–Cairo, IL. Town shown in bold: NM–New Madrid, MO. Features shown: Crowley’s Ridge; RL–Reelfoot Lake. Lake County project area shown within red box and location of Figure 15 is shown in dashed box (modified from Ward, 2016).
Figure 15. Generalized cross section of the Mississippi River floodplain and adjacent upland area in Lake and Obion Counties, TN. Age of Upland Complex is from Van Arsdale et al. (2014a; 2014b) and age of loess is from Pigati et al. (2015) and Markewich et al. (1998; 2011).
2.2 Faulting and Seismicity within the NMSZ and Lake County

Several faults have been mapped in and adjacent to Lake County. The Axial fault (AF) is a near-vertical NE-striking, dextral, strike-slip fault that is the southwestern arm of the NMSZ. The AF is mainly defined by seismicity but has also been imaged using seismic reflection (Johnston and Schweig, 1996; Csontos and Van Arsdale, 2008; Csontos et al., 2008; Magnani and McIntosh, 2009; Guo et al., 2014; Magnani et al., 2017). It is believed to be responsible for the earthquake of December 16th, 1811 $M$ 7.5 (Fig. 16) (Cramer and Boyd, 2014) and is thought to bisect the Reelfoot reverse fault into two segments. Guo et al. (2014) interpret 20 – 25 m of vertical displacement at the base of the Quaternary alluvium on the axial fault. Woolery and Almayahi (2014) suggest that the Axial fault continues to the northeast as a transpressional strike-slip zone into western Kentucky. The north segment of the NMSZ is a near-vertical, NE-striking, dextral, strike-slip fault known as the New Madrid North fault (NMNF). Again, whereas seismicity mainly defines the location of the NMNF, it has also been mapped using seismic reflection techniques and borehole mapping (Pryne et al., 2013). Subsurface mapping has the NMNF extending as the Charleston uplift through Mississippi County, Missouri (Pryne et al., 2013) and southwest to the western Reelfoot rift margin (Van Arsdale et al., 2013). The NMNF is thought to be responsible for the January 23rd, 1812 $M$ 7.3 New Madrid earthquake. The Risco fault (New Madrid West fault) is a west-striking, left-lateral, strike-slip fault that is the west-trending arm of the NMSZ (Csontos et al., 2008). It is identified by its earthquake foci (Fig. 16) and there is no subsurface geologic information. The Risco fault appears to continue west of the western margin of the Reelfoot rift (Van Arsdale et al., 2013). The Reelfoot fault is split into two segments divided by the AF (Figs. 5 and 16). The Reelfoot North fault and the Reelfoot South fault strike northwest (Csontos and Van Arsdale, 2008, Boyd et al., 2015). Both have a steep,
~ 72° southwest-dip from the shallow subsurface to a depth of ~ 4 km. However, below ~ 4 km the Reelfoot North fault dips ~ 32° SW and the Reelfoot South fault dips ~ 44° SW (Csontos and Van Arsdale, 2003). The Reelfoot scarp is a fault-propagation fold of the deeper Reelfoot fault expressed at the surface as a down-to-the-northeast monocline. This monocline bounds the eastern margin of the Tiptonville dome and the western margin of the Reelfoot Lake basin (Fig. 17). The deep Reelfoot fault is the location of much of the seismicity of the NMSZ (Russ, 1982; Stephenson et al., 1995; Van Arsdale et al., 1995, 1998; Purser, 1996; Purser and Van Arsdale, 1998; Guccione et al., 2002, Csontos and Van Arsdale, 2008; Csontos et al., 2008; Greenwood et al., 2016). Hanging wall deformation above the Reelfoot fault uplifted the Lake County uplift (LCU) and Tiptonville dome (TD) (Fig 17). The LCU is a fault-bounded topographic uplift with as much as 11m of relief above the Mississippi River floodplain along the Reelfoot scarp monocline that has played a major role in the local course of the Mississippi River (Russ, 1982; Guccione et al., 2002). There are three primary uplifted structures in the stepover zone: Lake County uplift, Tiptonville dome, and Ridgely ridge (Russ, 1982; Stephenson et al., 1995).

Stephenson et al. (1995) mapped in the subsurface the Cottonwood Grove fault and the Ridgely fault, which bound Ridgely ridge to the west and east respectively. They interpreted the Ridgely fault to be a near-vertical northeast-striking, right-lateral, transpressive strike-slip fault with numerous splays and mini-horst blocks. The Ridgely fault vertically displaces the Cretaceous/Paleozoic unconformity ~ 24 m and the Paleogene units ~ 20 m. They interpret the Cottonwood Grove fault also to be a northeast-striking, right-lateral, transpressive strike-slip fault. Both faults are responsible for the uplift of Ridgely ridge, which in the landscape is ~ 5 m higher than the surrounding Mississippi River floodplain (Stephenson et al., 1995). Guo et al. (2014) interpret that the base of the Quaternary is displaced ~ 20 – 25 m by the Cottonwood
Grove fault. The Cottonwood Grove and Ridgely faults parallel the strike and near-vertical dip of the Axial fault, but are not currently seismically active. Van Arsdale et al. (1998) suggest that Ridgely ridge is a northeastern continuation of the Blytheville Arch.

A mini-sosie seismic reflection survey along the southern margin of Reelfoot Lake imaged the Reelfoot South fault (RSF), the Cottonwood Grove fault (CGFZ), and Ridgely fault (RFZ). The RSF displaces the top of the Paleozoic by 70 m, Cretaceous by 60 m, Midway Group by 40 m, Wilcox Group by 30 m, and the Eocene/Quaternary unconformity by 15 m (Purser, 1996; Purser and Van Arsdale, 1998; Van Arsdale et al., 1998). To the southeast near the Mississippi River bluffs, the RSF displaces the top of the Paleozoic by 65 m, Cretaceous by 40 m, Midway Group by 31 m, Wilcox Group by 20 m, and Memphis Sand by 16 m (Greenwood, 2016; Greenwood et al., 2016). Greenwood et al. (2016) argue that the RSF is not segmented by right-lateral displacement on the CGFZ or the RFZ, rather the RSF has acted as one continuous fault zone across the CGFZ and RFZ since the Late Cretaceous. Displaced Quaternary stream terraces and 6 m displacement of the Upland Complex within the Mississippi River bluffs just to the east of Lake County in Obion County signify that uplift occurred both on the Mississippi River floodplain and in the uplands and that the RSF continues southeast as does the Tiptonville dome hanging wall deformation (Greenwood, 2016; Greenwood et al., 2016).
Figure 16. Earthquakes recorded between 1979 and 2006 in the New Madrid seismic zone (CERI Earthquake Catalog) are illustrated as black dots, with the approximate locations of the three very large 1811-1812 earthquakes with stars. AF – Axial fault; CA – Cairo, Illinois; C – Charleston, Missouri; N – New Madrid, Missouri; NMNF – New Madrid North fault; RF – Risco fault (New Madrid West fault); RFNF – Reelfoot North fault; and RFSF – Reelfoot South fault. Inset box shows Mississippi embayment and Mississippi River valley area. EM – Eastern Reelfoot rift margin; H – Helena, Arkansas; M – Memphis, Tennessee; MVB – Mississippi River valley bluffs; WM – Western Reelfoot rift margin. Dashed lines on inset reveal the connection of the Reelfoot rift with the Rough Creek graben in Kentucky (from Van Arsdale et al., 2013).
Odum et al. (1994, 1998) conducted seismic reflection along Hwy. 78 northeast of Tiptonville and interpreted the New Markham fault (NMF) that crosses under the highway near the community of New Markham, Tennessee. They interpreted the NMF as a north-striking, right-lateral, strike-slip fault, which they projected to trend south from the northeastern margin of the LCU into Reelfoot Lake where a scarp (possible fault scarp) at the bottom of Reelfoot Lake may connect the NMF and the CGFZ. Purser (1996), Purser and Van Arsdale (1998), and Van Arsdale et al. (1998) suggest that if the two faults are indeed connected they may be considered a single fault with a change in strike from NE to N (Fig. 17). Guo et al. (2014) offer a different interpretation from their Mississippi River seismic profile in which the NMF is thought to cross the Mississippi River further to the west and may be a splay (reverse fault) of the master Reelfoot fault (Fig. 18). Guo et al. (2014) also suggest that the New Markham fault is parallel to that of the Reelfoot scarp and that it displaces units from the Paleozoic to the Paleogene and possibly into the Quaternary.
Figure 17. Interpretation of the New Markham fault from Odum et al. (1994; 1998) where it crosses Hwy 78 shown with solid line and continues to the north and from Van Arsdale et al. (1998) where the New Markham fault may cross Reelfoot Lake as a linear scarp and possibly connects with the Cottonwood Grove fault. Inset figure (A) shows regional faulting and seismicity (Johnston, 1996). Inset figure (B) shows previously interpreted fault-linking configuration of the NMSZ (from Van Arsdale et al., 1998).
Figure 18. Guo et al. (2014) interpretation of the New Markham fault (NMF) as a northwest-striking splay of the Reelfoot fault that parallels the Reelfoot scarp. Mississippi River seismic lines M3, M4, M5, and M6 collected by Magnani and McIntosh (2009) (from Guo et al., 2014). A small series of presumably splaying faults cross the Mississippi River between marine seismic lines M5 and M4 (Magnani and McIntosh, 2009; Guo et al., 2014).
3. METHODS

3.1 Data Collection

Lithological logs from Lake County, and within a 4-km buffer zone, were collected from the Tennessee Department of Environmental Conservation (TDEC), the Tennessee Department of Transportation (TDOT), the United States Army Corps of Engineers (USACE), and the Center of Applied Earth Science and Engineering Research (CAESER). Lithologic logs from the North American Coal Company, housed in CAESER, are lignite exploration logs (Fig. 19); 34 for Lake County and 43 for buffer zone counties. The purpose of the buffer zone was to produce more accurate maps of Lake County by removing mapping edge effects. The lignite exploration logs record lithologic information for depths up to 300 ft. (~ 91 m) and some are accompanied by geophysical logs. The geophysical logs contain gamma ray and resistivity measurements, which may help identify lithology. Additional lithologic logs include 116 boring logs along the levees (USACE), 10 boring logs for bridges, railroads, and highways (TDOT), 4 boring logs of municipal water wells, 129 boring logs for irrigation and residential wells (TDEC), and 11 petroleum exploration well logs housed in CAESER. The boring depths vary, but typically are 30 – 200 ft. (9 – 61 m) for USACE borings, between 30 – 100 ft. (9 – 30 m) for TDOT, between 60 – 120 ft. (18 – 37 m) for TDEC residential and irrigation wells while municipal well depths range between 700 – 800 ft. (213 – 244 m), and 1800-3000 ft. (549 – 914 m) for the petroleum exploration wells.

Depths to stratigraphic tops from seismic reflection data were included from publications by Purser and Van Arsdale (1996), Van Arsdale et al. (1998), Csontos and Van Arsdale (2008), Guo et al. (2014), and Greenwood et al. (2016) (Fig. 20). When depth estimates of stratigraphic tops were not in a publication, conversion from two-way travel time to depth was conducted
using published interval velocities (Table 2). Depths of subsurface reflectors (stratigraphic tops) were then converted into elevation relative to sea level.

### 3.2 Data Interpretation and Entry

Stratigraphic picks were made from the interpreted lithologic logs and published seismic reflection data. Within the Quaternary Mississippi River floodplain section, maps were made at 5 ft. (~ 1.5 m) depth intervals. Tops of the Eocene, Memphis Sand, Flour Island, Fort Pillow Sand, Old Breastworks, Porters Creek Clay, Clayton, Late Cretaceous, and Paleozoic strata were picked (Appendix A) but structure contour maps were only made of the tops of the Eocene, Late Cretaceous, and Paleozoic strata.

All data including top of unit elevations and unit thickness were compiled into a single Excel 2016 spreadsheet and into separate spreadsheets for each individual geologic unit (Appendix A). Units of measure used in this study include both feet (ft.) and meters (m) because most of the drilling records are in feet. The latitude and longitude of each boring was copied from the drilling log to the spreadsheets and were then converted into Decimal Degrees (WGS 1984) and then projected into Universal Transverse Mercator (UTM) to construct geometrically accurate 3-D projections of the subsurface geology. Surface elevations of the borings and seismic line shot points were extracted from a LiDAR-sourced digital elevation model (DEM) (Fig. 21). The DEMs were created in Global Mapper 18.2 and were exported as ASCII files into ArcMap 10.3.1. The reason for doing so was because of Global Mapper’s ability to read LAS.zip (ZLAS) files, which are LiDAR point cloud files from the USGS Digital Elevation Database. Ground surface elevations were extracted using ArcMap 10.3.1 Spatial Analyst tools (Extraction – Extract Values to Points) and Data Management tools (Conversion – Table to Excel).
3.3 Structure Contour Maps

Structure contour maps were made of the top of the Eocene, Late Cretaceous, and Paleozoic sections. Unfaulted structure contour maps were created in ArcMap 10.3.1 using the Natural Neighbor interpolation method (Pryne, 2012), which allows for smooth, geologically reasonable, contouring and for the removal of ‘bullseye’ artifacts seen in other interpolation methods. Faulted structure contour maps were then made of these surfaces using the Spline with Barriers interpolation method, which allows for the introduction of faults and abrupt surface changes into the interpolation and for the smoothing of contours to produce a geologically reasonable, interpolated stratigraphic surface. Faults that were used for the Spline with Barriers method are previously interpreted by other authors. The basis for these faults are either defined by seismicity or constrained by previously conducted seismic reflection surveys.

The first step was to import the stratigraphic top data from the Excel 2016 spreadsheets (Appendix A) into ArcMap 10.3.1 as individual tables of each geologic unit. These tables were exported as shapefiles (.shp) so that they could be displayed as point features by using their XY coordinates. The coordinate system in which XY coordinates were projected is WGS 1984 UTM Zone 16N. Natural Neighbor (Spatial Analyst -> Interpolation -> Natural Neighbor) was used to produce the unfaulted contour maps. Cubic Convolution was selected for the pixel cell resampling method because it retains the high detail of the raster at large scale. The classified symbology was selected and the classification method was set to a defined contour interval, which for the top of the Eocene is 5 m, Late Cretaceous 10 m, and Paleozoic 10 m.

Shapefiles (polylines) were constructed to represent published mapped faults within Lake County. This required georeferencing figures from previous publications and to overlay them with 25 – 50 % transparency on top of the DEMs. This ensured that faults were located
accurately. The fault shapefiles were then merged into a single feature class. This is necessary because the interpolators only allow for a single feature class to act as barriers. The Spline with Barriers method was then selected from the 3D Analyst tools to produce the interpolated, faulted surface for each unit.

3.4 Cross Sections

Cross sections were developed using ArcMap’s Stack Profiles tool and proprietary software tools used in ArcMap. The proprietary tools which were provided by Fugro USA Marine, Inc. (Fugro), create cross sections based on manually entered parameters such as the search distance of borings from cross section line, vertical exaggeration, and other functionality not used in this report. The non-proprietary Stack Profile tool was initially used to construct normal and fault-introduced cross sections for the geologic units including the entire Quaternary, Paleogene, Cretaceous, and Paleozoic. However, this tool proved insufficient for lack of user interface and control as the vertical exaggeration and size of the cross section could not be manually adjusted. Thus, the Fugro toolset was chosen for developing the final cross sections.
Figure 19. Example of a lithological log from a lignite exploration boring from North American Coal Company.
Figure 20. Seismic reflection survey across the Reelfoot South fault from Greenwood et al. (2016) shot just east of Lake County in Obion County. Geologic units: ? – reflector in the Claiborne Group; Tc – Top of Memphis Sand; Tw – Top of Wilcox Group (Flour Island); Tp – Top of Porters Creek Clay; K – Top of Cretaceous; Pz – Top of Paleozoic.

Table 2. Interval velocities of the Quaternary, Paleogene, and Cretaceous sections and depth conversion equation (Guo et al., 2014; Guo, personal comm. 2018).

<table>
<thead>
<tr>
<th>Stratigraphic Unit(s)</th>
<th>RMS Velocity Function (km/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>1.7</td>
</tr>
<tr>
<td>Paleogene</td>
<td>2</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>2.7</td>
</tr>
</tbody>
</table>

TWT - Depth Conversion Equation
Depth = (TWT (s) / 2) * RMS Velocity Function (km/s)
Figure 21. Topographic relief map of Lake County and the mapped 4-km buffer zone surrounding Lake County. Colored DEM is clipped from the grayscale DEM (LIDAR_4KM). Elevations of boreholes and seismic reflection lines were extracted from these rasters. T-Tiptonville, R-Ridgely, RL-Reelfoot Lake.
3.5 Isopach Maps

Isopach (sediment thickness) maps were made of the entire Quaternary alluvial section, the Paleogene and the Late Cretaceous using the Natural Neighbor algorithm in ArcMap 10.3.1. as well as the Spline with Barriers method.

3.6 3-D Quaternary Geologic Model

A surficial geologic map and a 3-D Model of the uppermost 300 ft. (~100 m) was developed from 336 lithologic logs to show the detailed Quaternary alluvial deposits beneath Lake County. The model consists of 5 ft. (1.5 m) depth intervals that show the lateral distribution of the alluvial sediments within that 5 ft. (1.5 m) slice (Pryne et al., 2013). Sediment types were assigned a numerical value within Excel 2016 (Table 3). These values were assigned to lithologies, described in well logs, based on grain size starting with gravel as value ‘0’ to clay as value ‘6’. Eocene sediments were assigned a value of ‘7’ (Pryne, 2012). A spreadsheet containing the data was imported into ArcMap 10.3.1 for map surface interpolation. The Natural Neighbor interpolation method from Spatial Analyst tools was chosen for the Mississippi River alluvium mapping because this algorithm best honored the assigned numerical values for lithological classification. The interpolation assigned raster values to the pixels between well locations based upon the weight and distance between data points. This process created a raster of values with decimal ranges between the initially assigned values. The Raster Calculator tool was utilized to multiply all pixel values by 100 to make whole number values which would then be used for the conversion of raster values to integer. Raster values were then converted to integer values using the Raster to Integer conversion tool to remove the decimal points. Afterwards, the Raster to Polygon tool was used to more precisely classify lithologies around data points (Pryne, 2012). Due to the range of values produced for the Polygons, in this case
from 0 to 700, and the uncertainties between points, manual adjustments of the polygon classifications were needed to refine the lithological maps. The time needed to perform this manual operation was greatly reduced by introducing the data points from the spreadsheet as a shapefile and by opening individual depth layer attribute tables to validate assigned lithologies, both pre-interpolation and post-interpolation, so that the most reasonable polygon maps could be created. The polygonal surfaces were then imported into ArcScene 10.3.1 and were stacked by their layer depth in 5 ft. sheets from the ground surface to 300 feet deep. Surfaces were then extruded, 0 ft. for the surface layer and -5 ft. for all other sediment layers to account for spatial gaps between layers so that the model was continuous. Layers can be deactivated and reactivated so that each 5 ft. (1.5 m) layer within the Mississippi River alluvium of Lake County can be examined in the three-dimensional model. A separate document illustrating each 5 foot interval can be found in Appendix B1 and a video provides a demonstration of the 3-D Model when rotated and viewed in pseudo three-dimensional space in Appendix B2.
Table 3. Values assigned to lithologies for the 3-D Quaternary Model

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy Gravel</td>
<td>0</td>
</tr>
<tr>
<td>Sand</td>
<td>1</td>
</tr>
<tr>
<td>Silty/Clayey Sand</td>
<td>2</td>
</tr>
<tr>
<td>Loam</td>
<td>3</td>
</tr>
<tr>
<td>Silt</td>
<td>4</td>
</tr>
<tr>
<td>Clay/Silt</td>
<td>5</td>
</tr>
<tr>
<td>Clay</td>
<td>6</td>
</tr>
<tr>
<td>Eocene</td>
<td>7</td>
</tr>
</tbody>
</table>

3.7 Lake County 3-D Geological Model

A separate 3-D Geological Model was made that includes the Quaternary Mississippi River alluvium to the top of the Paleozoic. The Spline with Barriers method was chosen for this portion of the research to allow for the addition of faults in the interpolation process and to stay consistent with the surfaces from the finalized Structure Contour maps. Surfaces (e.g. top of the Paleozoic) are effectively split into separate fault-bounded grids and contoured. Spline with Barriers provide interpolated amounts of vertical displacement along the fault breaklines. Structure contour maps of the tops of the Eocene, Late Cretaceous, and Paleozoic sections were imported into ArcScene 10.3.1. These surface rasters were vertically stacked to the elevations of each geological unit’s surface raster. The model illustrates the geology and structure of Lake County in pseudo three-dimensional space. A video of the model is provided in Appendix C.
4. RESULTS

4.1 Structure Contour Maps

A principal objective of this research was to make a three-dimensional geologic model beneath Lake County, Tennessee. Faulted and unfaulted structure contour maps were generated for the top of the Eocene (Fig. 23), the top of the Cretaceous (Fig. 24), and the top of the Paleozoic (Fig. 25). Faults shown in Figure 22 were used for the faulted structure contour maps, faulted isopach maps, and the cross sections. Figures 23A and 23B are structure contour maps of the top of the Eocene. The top of the Eocene is high on the Tiptonville dome and low in the southwestern corner of the county and along the footwall (Reelfoot Lake basin) of the Reelfoot fault. The top of the Eocene on the northeastern portion of Ridgely ridge appears to be slightly lower in elevation than its southwestern portion.

In Figures 24A and 24B, the top of the Cretaceous is high in the northern half of the county and low in the southern half. It is high on both the Tiptonville dome and Ridgely ridge and low beneath Reelfoot Lake basin and lowest in the southwestern corner of the county. In Figures 25A and 25B, the top of the Paleozoic shares a similar distribution of highs and lows with that of the Cretaceous, but the top of the Paleozoic is highest beneath Ridgely ridge.
Figure 22. Map showing locations of Cross-Sections A-A’ (SW-NE), B-B’ (W-E), C-C’ (NW-SE), and D-D’ (W-E). Red and blue dashed lines represent Guo et al. (2014) and Odum et al. (1998) interpreted locations of the New Markham fault respectively.
Figure 23A. Structure contour map of the top of the Eocene.
Figure 23B. Faulted structure contour map of the top of the Eocene.
Figure 24A. Structure contour map of the top of the Cretaceous.
Figure 24B. Faulted structure contour map of the top of the Cretaceous.
Figure 25A. Structure contour map of the top of the Paleozoic.
Figure 25B. Faulted structure contour map of the top of the Paleozoic.
4.1.1 Cross-Sections

Several cross sections were developed from the structure contour maps (Fig. 22). Cross-Section A-A’ (SW-NE) (Fig. 26) crosses the county diagonally for 40-km and illustrates the subsurface stratigraphy and structure. Cross-Section B-B’ (W-E) (Fig. 27) is in the northern part of the county, Cross-Section C-C’ (NW-SE) (Fig. 28) is in the central part of the county, and Cross-Section D-D’ (W-E) (Fig. 29) is in the southern part of the county. Previously mentioned faults are crossed by different cross sections to see the types of displacement that they exhibit. Cross sections were developed in two parts including: 1) unfaulted tops of the Eocene, Cretaceous, and Paleozoic, and 2) faulted tops of the Eocene, Cretaceous, and Paleozoic.

4.1.1.1 Cross-Section A-A’

In Figures 26A and 26B, Cross-Section A-A’ crosses over faults BT-2, AF, BT-1, RF, and NMF. Shallowing of the Cretaceous and the Paleozoic in the northeast is evident whereas the top of the Eocene does not shallow to the northeast (Fig. 26A). Fault BT-2 in Figure 26B is apparent in the subsurface as the west-bounding fault of the Lake County uplift where it has down-to-the-southwest displacement. The Axial fault appears to have down-to-the-northeast displacement and it appears to displace the base of the Quaternary. Fault BT-1 is apparent in both Figures 26A and 26B as the west-bounding fault of the Tiptonville dome with down-to-the-southwest displacement up to the base of the Quaternary. The Reelfoot fault is clearly present and displaces all units. The New Markham fault is also apparent in Figures 26A and 26B with displacement on the Cretaceous and Paleozoic and possibly in the Paleogene though there is no displacement of the top of the Eocene.
**Figure 26A.** Cross-Section A-A’ (unfaulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozioc (purple). Vertical exaggeration = 25.

**Figure 26B.** Cross-Section A-A’ (faulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozioc (purple). Vertical exaggeration = 25.
4.1.1.2 Cross-Section B-B’

Cross-Section B-B’ (Figs. 27A and 27B) crosses faults BT-1, RF, and NMF. Fault BT-1 is not evident in Figure 27A, but once the fault is introduced in Figure 27B the Tiptonville dome (TD) becomes readily identifiable. The Reelfoot fault is clearly present in both cross sections and displaces each unit from the Paleozoic to the base of the Quaternary. The Reelfoot Lake basin appears to be underlain by a graben bounded by the Reelfoot fault and the New Markham fault.

Figure 27A. Cross-Section B-B’ (unfaulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozoic (purple). Vertical exaggeration = 10.
Figure 27B. Cross-Section B-B’ (faulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozoic (purple). TD - Tiptonville dome; RLB – Reelfoot Lake basin. Vertical exaggeration = 10.

4.1.1.3 Cross-Section C-C’

Cross-Section C-C’ (Figs. 28A and 28B) crosses faults BT-2, AF, CGFZ, and RFZ. Fault BT-2 is not evident in either cross section. The Axial fault is not apparent in Figure 28A though the Cretaceous does thicken at this location, but is evident in Figure 28B with up-to-the-west displacement on the tops of the Paleozoic and the Cretaceous. The Cottonwood Grove fault and the Ridgely fault zone are both evident in the subsurface and project up section as the west-bounding and east-bounding faults of the surficial Ridgely ridge respectively. There are also two apparent grabens lying adjacent to Ridgely ridge in Figure 28B revealing displacement down in the Paleozoic and the Cretaceous. All three faults appear to displace the base of the Quaternary.
**Figure 28A.** Cross-Section C-C’ (unfaulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozoic (purple). Vertical exaggeration = 15.
Figure 28B. Cross-Section C-C’ (faulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozoic (purple). RR – Ridgely ridge. Vertical exaggeration = 15.

4.1.1.4 Cross-Section D-D’

Cross-Section D-D’ (Figs. 29A and 29B) crosses the AF, CGFZ, and RFZ. Ridgely ridge and its bounding faults are evident in these cross sections, but displacement appears to diminish between Cross-Section C-C’ and Cross-Section D-D’. There appear to be previously unknown faults west and east of Ridgely ridge in Figures 29A and 29B. These unnamed faults displace the tops of the Paleozoic and the Cretaceous, but do not displace the top of the Eocene.
Figure 29A. Cross-Section D-D’ (unfaulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozoic (purple). Vertical exaggeration = 15.
**Figure 29B.** Cross-Section D-D’ (faulted) shows the Quaternary alluvium (peach), Eocene (gray), Cretaceous (green), and Paleozoic (purple). RR – Ridgely ridge. Vertical exaggeration = 15.

### 4.2 Isopach Maps

Isopach maps were made of the Quaternary alluvium (Fig. 30), the Paleogene (Fig. 31), and the Cretaceous (Fig. 32). These maps show where the greatest thickness of each unit exists within the county and provide information as to the subsurface faulting history and the sedimentary processes.

The thickness of the entire Quaternary alluvium ranges from 30 – 70 m in Lake County (Figs. 30A and 30B). In Figure 30B, the thickness is low on the northwestern portion of the
Tiptonville dome but thickens over the southeastern portion of the dome where it intersects with the northeast striking faults.

The thickness of the Paleogene is greatest in the southern portion of the county and thinnest in the north (Figs. 31A and 31B). Similarly, the Cretaceous (Figs. 32A and 32B) is thickest in the south, however, it also thickens in the northern part of the county.
Figure 30A. Quaternary alluvium isopach map.
Figure 30B. Faulted Quaternary alluvium isopach map.
Figure 31A. Paleogene isopach map.
Figure 31B. Faulted Paleogene isopach map.
Figure 32A. Cretaceous isopach map.
Figure 32B. Faulted Cretaceous isopach map.
4.3 3-D Quaternary Geologic Model

A 3-D Geologic Model of the Quaternary alluvium was made using 336 borings (Fig. 33). The model illustrates the predominantly clay and silt (green and blue) floodplain sediment within the upper 25 ft. The clay and silt deposits are thicker on the eastern side of the county where alluvial fan deposits from the Mississippi River bluff streams have deposited silt out onto the Mississippi River floodplain. The red, orange, and yellow colors are the point bar sands and sandy gravel channel deposits. Some sand deposits are found at the surface in Lake County and may represent earthquake liquefaction deposits and modern alluvium along the Mississippi River (Figs. 33 and 34). The Mississippi River point bar sequence sands and underlying channel sandy gravels are located from 25 ft. to a maximum of about 250 ft. in depth. Below the alluvium, Eocene deposits (gray) are in the subsurface of the county. The individual 5-ft. (1.5 m) alluvial layers can be found in Appendix B1, while a video animation of this model can be viewed in Appendix B2. In Appendix B1, the Mississippi River and Reelfoot Lake are in the first 100 ft. of the model. Accurate determinations of the Mississippi River bathymetry along the western margin of Lake County could not be obtained so a maximum depth estimate of 100 ft. has been inferred. Reelfoot Lake is assumed to be approximately 5 ft. deep over most of the lake, and so the lake water is only shown at the surface and the first 5 ft. depth interval.
Figure 33. Surface geology of Lake County and surface layer (0 ft.) of the 3-D Quaternary Model.
**Figure 34.** 3-D Geologic Model showcasing distribution of Quaternary alluvium under Lake County, Tennessee. Red is sandy gravel, orange is sand, yellow is silty sand or clayey sand, light green is an unknown mix with percentages of clay, silt, and sand, green is silt, light blue is clayey silt or silty clay, and blue is clay. Gray represents Eocene. Reelfoot Lake and the Mississippi River are black. Red line illustrates the location of the surficial Reelfoot scarp. Vertical exaggeration = 25.
4.4 Lake County 3-D Geologic Model

A 3-D geologic model from the land surface to the top of the Paleozoic of Lake County is illustrated in Figures 35 and 36 and is recorded as a video within a pdf document (Appendix C). In the model, the lidar dem acting as the ground surface and the top of the Quaternary alluvium overlies the tops of the Eocene (gray), Cretaceous (green), and Paleozoic (purple) of Lake County (Figs. 35, 36, and Appendix C). In Figure 35, the structure contour surfaces are stacked in ArcScene relative to mean sea level. In Figure 36, faults are extruded as vertical planes through the model to show the general configuration of the faults that underlie Lake County. In Appendix C, the mapped surfaces are also shown displaced by faults with the Reelfoot fault displacing the landscape. Some discrepancies exist in the model where geologic surfaces locally come into ‘contact’ when they should not. Such a case may be where displacement from a fault in a lower geologic section such as the Paleozoic has greater apparent vertical displacement than on a shallower section. This may result in the deeper geologic surface overprinting the shallower section. This is probably due to boring locations or shotpoints not being present near a fault.
Figure 35. NW-looking oblique view of the 3-D Surface to Paleozoic Geologic Model of Lake County developed in ArcScene 10.3.1. Modern surface (yellow), top of Eocene (gray), Cretaceous (green), and Paleozoic (purple) shown as stacked layers based on elevation (m). Vertical exaggeration = 15. Animation in Appendix C.
Figure 36. 3-D Geologic Surface to Paleozoic Model of Lake County developed in ArcScene 10.3.1. Modern surface (yellow), tops of Eocene (gray), Cretaceous (green), and Paleozoic (purple) shown as stacked layers based on elevation (m). Faults shown as vertical planes slicing through the geologic surfaces. Vertical exaggeration = 15. Animation in Appendix C.
5. DISCUSSION

5.1 Structure Contour Maps

The top of the Eocene structure contour maps (Figs. 23A and 23B) show that a structural high exists on the Tiptonville dome. Ridgely ridge appears less pronounced though some highs do exist along its southwesterly trend, more so in the faulted contour map. The Reelfoot Lake basin has limited information, but the top of the Eocene does appear to be structurally low. The top of the Eocene has a southerly trend of lows on the western side of the county.

The top of the Cretaceous (Figs. 24A and 24B) and the Paleozoic (Figs. 25A and 25B) show similar structural relief. Both interpolated surfaces show highs in the northern and eastern parts of the county while there are significant lows in elevation in the southwestern part of the county. Interestingly, the Paleozoic is between 40 to 100 m higher on Ridgely ridge than it is further to the north on the Tiptonville dome.

5.2 Geologic Cross-Sections

Four geologic cross sections were generated for Lake County. Three of the cross sections are W-E lines (B-B’, C-C’, and D-D’) and one is SW-NE (A-A’). Two sets of cross sections for each line were made and include the Eocene-Paleozoic section, and the faulted Eocene-Paleozoic section.

5.2.1 Cross-Section A-A’

Cross-Section A-A’ (Figs. 26A and 26B) illustrates a SW-NE profile of the subsurface in Lake County (Fig. 22). A gradual slope to the southwest of the tops of the Cretaceous and Paleozoic are evident in Figures 26A and 26B that is attributed to the formation of the
Mississippi embayment. The Axial fault and the Tiptonville dome backthrust, BT-1, displace the top of the Eocene (Fig. 26B) and appear to form a small graben. The Axial fault in cross section A-A’ (Fig. 26B) shows little displacement of the Cretaceous and Paleozoic although this is possibly due to the cross section not being perpendicular to the Axial fault like that in both Cross-Sections C-C’ (Fig. 28A and 28B) and D-D’ (Fig. 29A and 29B). When the faults are introduced in Figure 26B, the cross section reveals greater displacement of the Quaternary-Eocene contact, but less displacement on the top of the Cretaceous and the top of the Paleozoic across the Reelfoot fault. The area through which the cross section was run may not have had enough data control to show the displacements seen in seismic reflection data observed further to the southeast by Purser (1996), Purser and Van Arsdale (1998), and Van Arsdale et al. (1998). The Quaternary appears to be between 40 to 60 meters thick from the southwest to the Tiptonville dome where it may thin to 30 meters and then thicken up to ~ 75 meters thick around the Reelfoot Lake basin to the northeast, the Paleogene appears to thicken to the southwest up to 600 meters and thins in the northeast to approximately 550 meters. The Cretaceous thickens to the southwest but its thickness variation appears to be mostly controlled by faults with possible erosional processes in the southwestern portion of Lake County.

Another interesting detail which is apparent from these cross sections is the confirmation of the New Markham fault northeast of the Reelfoot fault in both the faulted and unfaulted cross sections. It does not show any displacement on the top of the Eocene, but it does reveal down-to-the-west displacement of the tops of the Cretaceous and Paleozoic. This may indicate that the New Markham fault became inactive sometime before deposition of the Jackson/Cockfield Formations or that perhaps it is not represented in the shallow section in this cross section due to a lack of boring data near Reelfoot Lake. The location of the New Markham fault at 30,000
meters (Fig. 26B) lies between the previous interpreted locations (Odum et al. 1998; Guo et al. 2014).

5.2.2 Cross-Section B-B’

Cross-Section B-B’ (Figs. 27A and 27B) illustrates a W-E profile of the northern part of the county (Fig. 22). The Paleogene is up to ~ 500 meters thick along the line and the Cretaceous is approximately 100 meters. Including the Quaternary’s thickness of 25 to 60 meters within the area of the cross section, this indicates > 600 meters of unconsolidated sediment overlying the Paleozoic carbonates. Cross-Section B-B’ crosses the Tiptonville dome backthrust (BT-1), the Reelfoot North fault, and the New Markham fault. The Reelfoot North fault in this cross section does agree with general displacements being greater in the subsurface (Figs. 27A and 27B), which is not seen on the Reelfoot South fault in Figures 26A and 26B. Fault BT-1 does not show any displacement in Figure 27A but does in Figure 27B. This either indicates lack of data combined with smoothed interpolation or that there is only minor displacement in the shallow section. The New Markham fault is once again present only displacing the deeper geologic units (Figs. 27A and 27B) and does not appear to displace the top of the Eocene.

5.2.3 Cross-Section C-C’

Cross-Section C-C’ (Figs. 28A and 28B) is a NW-SE oriented section that cuts through the center of the county. It crosses the Axial fault, the Cottonwood Grove fault, and the Ridgely fault. The Axial fault and the Ridgely fault show displacement in the cross sections. The Ridgely ridge appears to be a tilted, asymmetrical horst on all stratigraphic units. The Axial fault does not agree with previous interpretations by Guo et al. (2014) and Magnani et al. (2017). The Axial fault displaces the Quaternary – Eocene unconformity down-to-the-west, but it displaces the
Paleozoic and the Cretaceous down-to-the-east. This apparent structural inversion may be an artifact of the interpolation due to the limited drilling data though erosion or an inversion of faulting could still be the cause. The Cottonwood Grove fault displaces the base of the Quaternary to the Paleozoic down-to-the-west (Figs. 28A and 28B). Similar to the Axial fault, the Ridgely fault has down-to-the-east displacement on the tops of the Cretaceous and the Paleozoic, but down-to-the-west on the top of the Eocene. This inversion may be an artifact of the interpolation or it may be the result of erosion during the Quaternary. Erosion or actual tectonic inversion is likely more arguable for this because of the larger amount of both shallow boring and seismic data present within the immediate vicinity of Ridgely ridge.

The Paleogene is 500 – 550 meters thick and the Cretaceous is 100-150 meters thick along Cross-Section C-C’. Combined with a Quaternary thickness of approximately 50 meters, this equates to a range of ~ 620 meters to 750 meters of soft sediment overlying the Paleozoic along Cross-Section C-C’.

5.2.4 Cross-Section D-D’

Cross-Section D-D’ (Figs. 29A and 29B) is a W-E trending section that crosses the southern portion of Lake County. It crosses the Axial fault, the Cottonwood Grove fault, the Lake County uplift backthrust (BT-2), and the Ridgely fault. In Figures 29A and 29B, the Quaternary is on average about 50 meters thick and it is nearly 70 meters thick in the center of the cross section where there appears to be a large trough or Quaternary paleochannel that has cut down into the Eocene. Figure 29B shows the Axial fault displacing the top of the Eocene at the western margin of the trough. It seems unreasonable that this apparent vertical displacement is due solely to displacement on the Axial fault. This trough is assumed to be a paleochannel of the Mississippi River. However, it is reasonable to assume that the Axial fault did at one time
displace the top of the Eocene here, but has since been removed by scour and infill. Further east along the cross sections, the Cottonwood Grove fault and the Ridgely fault both displace the top of the Eocene. The Ridgely fault down-to-the-east displacement is similar to that of the Axial fault in this cross section but opposite to what has been seen in Cross-Section C-C’ where there is an inverse sense of displacement on the top of the Eocene. The cross sections paint an even more complex picture showing apparent displacement in the zone between the Axial and Ridgely faults. This strange complexity is attributed to the location of the cross section. Cross-Section D-D’ as seen in Figure 22 crosses an area where both the Cottonwood Grove fault and fault BT-2 are within very close proximity. It is possible that the location of the faults being located very close together may have greatly affected the faulted interpolation method imposed on the data and the appearance of this apparent complexity in the subsurface structure and stratigraphy. Though to note the style of deformation associated with the two faults, both faults essentially cause down-to-the-west displacement though it is assumed the Cottonwood Grove fault is the fault that actually displaces the base of the Quaternary and not BT-2. There are potentially unidentified faults further to the west and to the east in Cross-Section D-D’ (Fig. 29A and 29B) that appear to displace the Cretaceous and the Paleozoic but do not seem to influence the top of the Eocene (Figs. 29A and 29B).

5.3 Isopach Maps

Isopach maps developed for the entire Quaternary section (Figs. 30A – 30B), the Paleogene section (Figs. 31A – 31B), and the Cretaceous section (Figs. 32A – 32B) provide subsurface distribution and thickness of each mapped unit while also providing insight into the depositional and tectonic processes that have affected the geologic units.
Figures 30A and 30B show that the Quaternary section is thickest in the southwestern, eastern, and northeastern portions of the county where structure contour maps (Figs. 23A and 23B) reveal significant lows in the top of the Eocene. Predicted isopach thicknesses of the Quaternary greater than 80 meters possibly overestimate the highest recorded boring thickness of 76 meters.

Paleogene isopach maps (Figs. 31A and 31B) reveal thicker sediments in the southwest of the county parallel to the axis of the Mississippi Embayment. The Paleogene thins over the Tiptonville dome and thickens northeast of the dome and Reelfoot fault. In Figures 31A and 31B, there is a thickness difference of approximately 100 meters between the upthrown and downthrown fault blocks across the Reelfoot North fault possibly indicating concurrent faulting and higher deposition on the downthrown side of the fault. There is not sufficient drill hole data to determine any changes in thickness of the Paleogene section across the Reelfoot South fault. Ridgely ridge also has a thinner Paleogene section than the immediately adjacent area off of the horst.

The Cretaceous isopach maps (Figures 32A – 32B) show that the Cretaceous in Lake County is relatively thin with greatest thicknesses located in the southwest and in the north along the Mississippi River. The thickest Cretaceous deposit, in northern most Lake County come from Guo et al. (2014). Two thick Cretaceous sections in the southwest and in the lower central portion of the county are only constrained by a single oil and gas well each. The Cretaceous on the Tiptonville dome and on Ridgely ridge is thin.
5.4 3-D Quaternary Geologic Model

Figure 33 and Appendix B illustrate the 3-D Quaternary stratigraphic model encompassing the surface of Lake County to 300 ft. depth (91.4 m). The resulting model shows that surficial sediments up to around 25 ft. (7.6 m) are predominantly fine-grained Holocene silts and clays (blues and greens). From 30 ft. to 155 ft. (9.1 m to 47.2 m), the dominant sediment class are the coarse-grained (red, orange, and yellow) Quaternary clayey or silty sands, homogenous sands, and sandy gravels. Beyond these depths, the dominant sediment belongs to the Eocene (gray). The general order of strata is from top to bottom: clay and silt, sand, and sandy gravel. The greatest concentration of sandy gravel is from depths 60 ft. to 120 ft. (18.3 m to 36.6 m). Pryne (2012) mapped several paleochannels along the Sikeston ridge just north of Lake County in a 10 ft. model. Individual buried paleochannels are not evident in Lake County, rather it appears to consist of a larger series of connected paleochannels. Sandy gravels in Lake County cease at a depth of 230 ft. though there is a lower section of possible Quaternary or Eocene (Jackson Formation) sands below the gravel between 230 ft. to 250 ft. in the southwestern part of the county. Below 250 ft. (76.2 m), the section is all Claiborne Group with possible patches of Eocene-Oligocene Jackson Formation. A negative aspect to both the Quaternary model and the 3-D geologic model of Lake County is that ArcScene does not provide the best user interface for controlling and manipulating the models. It also has limited potential for exporting the 3-D models.

5.5 Lake County 3-D Geologic Model

The three-dimensional Lake County geologic model (Figs. 35, 36, and Appendix C) shows a generalized interpretation of the subsurface geology using ground surface geology and the faulted structure contour maps of the tops of the Eocene, Cretaceous, and Paleozoic. The
model animation in Appendix C reveals the subsurface to be more complex than previously thought. The Lake County uplift, Tiptonville dome, and Ridgely ridge are expressed well in the model and it demonstrates the structural lows seen in the southwest of the county. An evident problem in ArcScene is the lack of control of the data. The faults that cut through the county are not all vertical or near-vertical. Some such as the Reelfoot fault, both backthrusts, and the New Markham fault (not included in model) should have fault planes extruded at an angle to better represent the true sense of the subsurface deformation. A potential way to benefit this model would be to consider adding additional Paleogene units if they were better mapped in the region.
6. CONCLUSIONS

Lake County’s geology is complex and inadequately described in the literature despite its location in the NMSZ. Lignite boring logs, water well logs, petroleum exploration logs, geotechnical logs, and previously interpreted seismic reflection lines were used for mapping the subsurface geology of Lake County.

The Paleozoic and the Cretaceous gradually slope down to the southwest and are displaced by all previously interpreted and uninterpreted faults. Both the Paleozoic and the Cretaceous are shallowest under the Tiptonville dome and Ridgely ridge, but occur deepest under the Reelfoot Lake basin and the southwestern portion of the county. There are three newly proposed faults seen in Cross-Section D-D’. The unnamed proposed faults in Cross-Section D-D’ need additional seismic reflection surveying to confirm their existence, but a potential issue with the two proposed western faults is that they are located much closer to the Mississippi River and may not be easily accessible.

The top of the Eocene is highest under the Tiptonville dome, lowest under Reelfoot Lake, and low in the southwestern portion of the county. The top of the Eocene does not have the southwestern slope characteristically seen on the tops of the Paleozoic and the Cretaceous. The top of the Eocene is quite irregular and the irregularity of this contact between the Eocene and the Quaternary is likely due to a combination of erosion and faulting. These observations combined with the observed active seismicity of the New Madrid seismic zone indicate that the southwestern sloping of the Paleozoic and Cretaceous pre-dates Quaternary erosion and faulting. Consistent displacement seen across several faults also suggests active faulting during the Quaternary while others such as the New Markham fault appear deactivated.
The Quaternary section (Figs. 30A and 30B) is thickest in the northeast, southwest, and eastern parts of Lake County. The suggested cause of higher thicknesses in the northeast is mainly considered to be due to subsidence of the Reelfoot Lake basin. The high thicknesses in the southwest are also likely linked to subsidence. It is also likely that both locations could have experienced river channelization due to the suspected subsidence. The eastern high is not well explained in this study by faulting alone. It exists within the fault-bounded Ridgely ridge where expected thicknesses are expected to be lower. Due to these observations, it is more reasonable to associate it with Quaternary erosion and infill rather than Quaternary faulting though future shallow seismic surveying could resolve this. The base of the Quaternary is displaced by the Reelfoot fault, the Cottonwood Grove fault, and the Ridgely fault. The Quaternary may also be displaced by fault BT-1 and the Axial fault.

Clear fining-up sequences of the Quaternary alluvium can be seen in the 3-D Quaternary Model. Potential Quaternary paleochannels in Lake County do not appear to have individual pathways but appear to be interconnected in an anastomosing pattern which is consistent with that of a braided river. The 3-D Lake County Geologic Model illustrates the complexity of the subsurface structure. It also illustrates the structural highs and lows seen in the cross sections and the structure contour maps.

Future efforts that could resolve some of the complexity documented in this research would include collecting both S-wave and P-wave seismic reflection surveys. For example, seismic reflection P-wave surveying of the southwestern portion of Lake County would confirm or refute the mapped graben west of Ridgely ridge. Shallow S-wave seismic reflection and ground penetrating radar should be conducted across all the faults in Lake County to better document their Quaternary histories.
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APPENDIX A – MASTER SPREADSHEET

Appendix A is an Excel 2016 spreadsheet that contains the list of boring logs and seismic reflection data used for the mapping in this thesis. The spreadsheet has labeled tabs detailing geologic information about individual stratigraphic units or tabs that were specifically used in the making of my Quaternary model. The first tab that appears when the appendix is viewed will be the Quaternary to the top of Eocene data. These data include a variety of information such as geologic unit thickness, depths, elevations, and other general information such as boring depths, locations, and data source for each specific boring or shot point.
APPENDIX B – QUATERNARY LITHOLOGIC MODEL

Appendix B1 contains the 2-D Quaternary lithologic units that are in two formats including pdf or as a Word 2016 document. Appendix B1 is laid out as the entire series of the 5-ft. (1.5 m) incremental layers from the surface down to 300 ft. (~91 m) deep.

Appendix B2 contains a video presentation of the 3-D Quaternary lithologic model in several formats including pdf, a PowerPoint 2016 presentation, and mp4. The different formats are presented for wider access to a viewing audience. The classification of each sediment type is shown by color and is the same in Appendix B1 and B2. Appendix B2 also includes the introduction of faults so that the viewer has a better understanding of the location of these faults and their possible influences on lithologic variation.
APPENDIX C – LAKE COUNTY 3-D GEOLOGIC MODEL

Appendix C contains the video presentation of the 3-D geologic model developed for Lake County. It shows the lidar imaged Quaternary alluvium surface underlain by the top of the Eocene, top of the Cretaceous, and top of the Paleozoic. These layers are the faulted structure contour maps. The model incorporates faults as vertical planes to show the interpreted vertical displacements. The only fault that clearly displaces the ground surface lidar map is the Reelfoot North fault. The video can be viewed in either the pdf or the PowerPoint 2016 presentation formats.