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The Red River in southwest Arkansas creates a changing environment that has had a large impact on those who lived there, including floods, channel movements, and the erosion of whole landforms. River movements, and the resulting oxbow lakes, create an environment favorable to fishing. This study uses historical documents, lidar data, and coring methods to sequence past river movements around a multiple-mound Caddo ceremonial center, the Crenshaw site. This information is used to determine the likely location of the Red River at the time the ancient Caddo constructed the mounds and to note where portions of the ancient site may have been destroyed by subsequent river migration. The cores indicate that the Red River cut off an active channel on the west side of Crenshaw, creating an oxbow lake. The Caddo (or their antecedents) constructed Mound A and the causeway on the point bar surface of a meander bend that has not been buried by significant overbank sediment. This suggests that the Caddo constructed Mound A, the causeway, and Mound E (on the south end of the point bar) after the channel was abandoned and became an oxbow lake. Areas to the east, northeast, northwest, and to the south were destroyed by more recent river movements that crosscut landforms on which the Caddo built the mounds, suggesting that the site was larger than what remains today. Clearly, the Caddo were active managers of their environment. Linear topographic patterns indicate large portions of the landscape, beyond the mounds, were crafted by the ancient Caddo.

Introduction

Understanding the geomorphology of archaeological sites is useful for determining how the surrounding landscapes changed through time, informing us of how these changes affected the ancient inhabitants and the preservation of the sites themselves. River migration can completely erode entire landforms. New landforms are deposited behind the migrating meanders, leaving no trace of the settlements and people that may have existed in the past. Understanding the changing position of a river channel over time may reveal locations where undiscovered sites, especially buried sites, may be found. It also may enable archaeologists to determine the position of the river at the time of occupation and improve our knowledge about the ecology of the landscape at the time of occupation (Stafford 1995). These studies can also aid in understanding the extent of past human occupation in space because areas that have been destroyed by the river create abrupt modern site boundaries. If cultural materials are found near these boundaries, it might indicate that parts of the site have been destroyed by past river action (e.g. Guccione 2008; Guccione et al. 1998; Pearson 1982). Beyond understanding landforms, the presence of oxbow lakes also has implications for how we understand the ecology of the site and by extension, the diet of the people who lived there. Oxbow lakes are resource-rich areas for fresh water and biota (Girard 2012; Milner 2004; Smith 1978) and may have played a role in how people selected the site's location and how they organized their settlements.

The Crenshaw site (3MI6), located along the Red River in southwest Arkansas, is a multiple-mound Caddo ceremonial center of great significance to the Caddo and archaeologists (Figure 1). The Caddo and their antecedents (Fourche Maline) occupied Crenshaw between at least A.D. 900 and 1400 (Samuelsen 2014). The site had six mounds (A through F) at the time of Clarence B. Moore's (1912) test excavations. While Mounds A and E remain mostly intact today, Mounds B, C, and D have been excavated or destroyed and three

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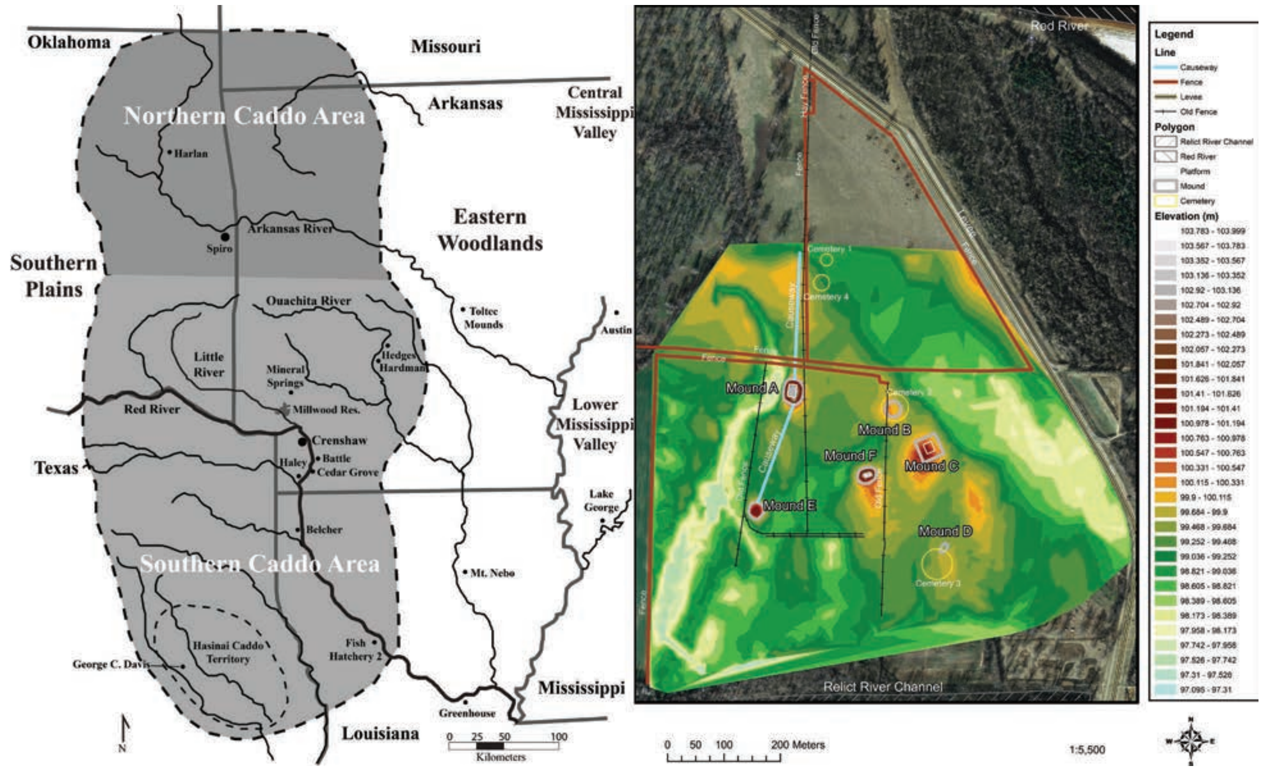

Figure 1. The Crenshaw site in the Caddo Area (*left*, from Samuelsen and Potra 2020:Figure 2) and a map of the site (*right*) with historic fencing shown.

trenches have been dug through Mound F (Samuelsen 2009). Several oxbow lakes and linear or curvilinear depressions exist around the site, making it difficult to determine which partially infilled channel was the river's location during the Caddo occupation of the site.

This study will analyze all known abandoned channels that surround Crenshaw and use historic documents and maps, Light Detection and Ranging (lidar) data, and subsurface core information to test which, if any, of the oxbow lakes or depressions west of the site may have been an active Red River channel or an oxbow lake during site occupation. Additionally, the location of the site relative to various younger channel positions will help assess how much of the site may have been destroyed by river action. This provides information about Caddo settlement patterns through the study of the spatial extent and temporal length of the ancient Caddo occupation, the nature of ritual or domestic use, and how the Caddos interacted with their environment.

Past geomorphological studies and previously hypothesized channel locations for Crenshaw enable construction of testable hypotheses. Charles Pearson (1982) conducted a geomorphological study of the Red River in the Great Bend region and identified fluvial landforms (Figure 2) that were younger than A.D. 1580 based on the location and fill of meander scars and an 1887 survey map (United States Engineer Department 1886-1892). Schambach (1996:Figure 5.2) proposed

Figure 2. Recent fluvial abandoned channels and oxbow lakes. Blue areas are younger than about A.D. 1550 (Pearson 1982).

that the low topographic area just west of Mounds A and E as the location of the active river at the time of site occupation (Figure 3). This paper seeks to test this hypothesis. There are at least two modern oxbow lakes near Crenshaw and west of the present Red River. There are also several other linear or curvilinear depressions that may represent an active or abandoned channel during site occupation. Because the Red River currently is east of the archaeological site, it is possible that the river migrated across and eroded part of the site after the channel was abandoned. Alternatively, if the river avulsed (or moved due the active channel being cut off) to a new eastern location without migration, all or part of the site could be preserved.

The Red River in Southwest Arkansas

The Red River valley in southwest Arkansas (Figure 4) includes locally preserved Pleistocene terraces that flank a broad Holocene floodplain cut into Tertiary uplands (Pearson 1982). The floodplain has a low gradient of 0.1 to 1.1 m/km with high local aggradation in the meander belt and small net aggradation (Guccione et al. 1998). Near Crenshaw in the Great Bend Region of the Red River, the 20 km wide Holocene floodplain includes a 4.5 km-wide active meander belt on the east side of the valley with most of the backswamp lying on the west side of the valley. Crenshaw is preserved in the west side of the meander belt. The archaeological site is separated from the present channel by a recently constructed levee to control flooding (see Figure 3). West of the meander belt is a 15 km-wide backswamp that borders Tertiary uplands. East of the meander belt, small areas of backswamp border the Tertiary uplands. No Pleistocene terraces are preserved near Crenshaw.

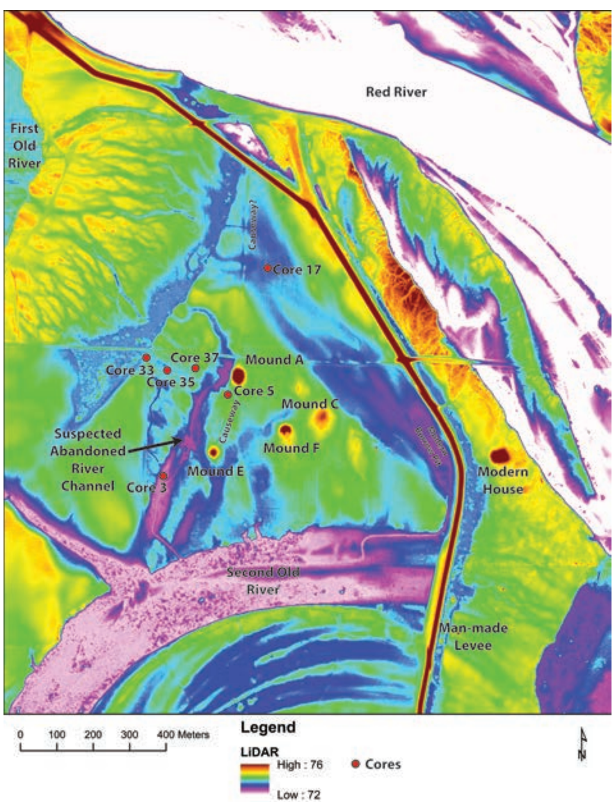

Figure 3. Lidar map of Crenshaw and surrounding areas with core locations. A suspected abandoned channel, First Old River, Second Old River, and a modern constructed levee are marked.

Crenshaw is half-way between the river and the boundary of the meander belt with the backswamp (see Figure 2). At the meander-belt margin, natural levees grade into the backswamp. Within the meander belt, abundant oxbow lakes mark the locations of previous channel positions. On the inside of the active and abandoned meander bends are sandy point bars and along the outer margins of the channels are silty natural levees that bury older alluvial deposits.

Before modern intervention, the Red River channel frequently shifted positions and imposed great havoc on the people in this area (Bowman 1911; Fenneman 1938; McCall 1988; Schambach 1993). Banks of the Red River are easily erodible and the low gradient result in constant migration. Rafts of woody debris, formed by collapsing of vegetated channel banks, caused floods and blockages of the river. One historic source of flooding in the area that greatly impacted the valley environment was the Great Raft, which extended north of Natchitoches, Louisiana, for nearly 320 km and blocked the Red River channel with fallen trees (McCall 1988). The Raft was not fully cleared until its final removal in 1873 (McCall 1988).

Methods

Historic maps and aerial photographs were collected and analyzed to establish a timeline of river meandering and subsequent abandonment of river channels that became oxbow lakes. The landforms associated with oxbow lakes can be relatively dated using cross-cutting relationships. Combining this information with known

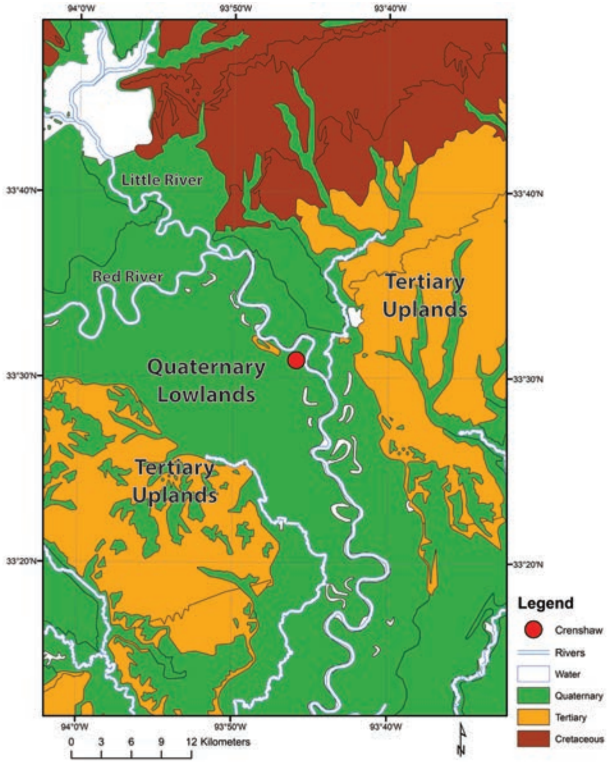

Figure 4. Geology of the Red River valley surrounding Crenshaw. Tertiary uplands surround the Quaternary lowlands on either side of the site.

site locations and their estimated date ranges confirmed the estimated landform age (see Figure 2), as done by Pearson (1982) in this region. This information was combined with lidar data around the site (see Figure 3) to better identify topographic anomalies related to fluvial events. Lidar data are measured in meters above sea level. Lidar point cloud data are from the United States Geological Survey (USGS 2020) and originally collected by the Natural Resources Conservation Service in 2016 through 2017. The data resolution was ~50 cm and was processed to remove trees and other above surface features before being interpolated to a 25 cm raster grid.

Five cores, Crenshaw Cores 3, 5, 33, 35 and 37, were taken near and within the suspected abandoned river channel west of Mounds A and E (see Figure 3). The cores were sampled with a Giddings Soil Probe drilling rig. A plastic sleeve was placed inside a five-centimeter diameter metal tube 130 cm in length. The rig pushed the metal tube into the ground until the top of the tube was just above the ground surface, filling the tube with soil. The plastic sleeve was then extracted from the metal tube. The process was repeated with new sleeves to core deeper. Coring stopped at "refusal" when the rig could not push the metal tube any deeper into the ground.

Core 3 was located within a linear depression, a possible partially infilled abandoned channel. The remaining cores (Cores 33, 35, 37, and 5) were sampled in a transect near and west of Mound A to evaluate: 1) if the linear depressions near the mound are abandoned channels; 2) if the depressions extend to the north but have since been infilled; 3) if the depression west of Mound A is an extension of an abandoned channel, a borrow pit for the mound, or both.

Cores were cut in half and one half of each was used for the sediment description, sampling, and grain-size analysis (see Appendix). The other halves were saved for future use and are stored at the Arkansas Archeological Survey Coordinating Office. Core descriptions include color, using the moist Munsell color system; texture, using USDA Soil Survey nomenclature; presence of roots and root pores, redoximorphic features and cutans, and soil structure. Cutans, or clay films, are likely formed as stress cutans during fluctuating relatively wet (expansive) and dry (shrinkage) conditions. Soil horizons and stratigraphic boundaries were interpreted and classified using standard USDA terminology (Laurent 1984). Laurent's (1984) description of soils in the region provided a baseline for comparison with the described soil properties. The depth of soil and stratigraphic boundaries were mathematically adjusted to the actual depth below ground surface to account for any expansion or compression of the core during drilling. Elevations of boundaries are relative to the lidar-based surface elevation of the core location.

Thirty selected samples from the cores were used to quantify the textures estimated in the core descriptions, following Day (1965). Some horizons were not sampled, and other horizons were thick and multiple samples were analyzed. Oven-dried samples were gently ground using a mortar and pestle and wet sieved with deionized water to separate the sand fraction from the silt and clay fractions. The sand fraction was dry sieved to separate gravel, very coarse sand, coarse sand, medium sand, fine sand, and very fine sand. Pipetted samples at appropriate times and depths were used to subsample a slurry for three silt fractions and one clay fraction. Oven-dried and desiccated weights of all sand, silt, and clay fractions were used to calculate the weight percent of each fraction.

Results

Fluvial Sequencing

Crenshaw, west of the current river, is southeast of the First Old River oxbow lake, and north of the Second Old River oxbow lake. Based on cross-cutting relationships, the archaeological site is located on a landform older than both these abandoned channels. Maps from 1842, 1864, 1887, 1912, 1929, and 1936 and the survey for the Miller County line in 1874 (Guccione et al. 1998) support the age estimates of First Old River forming between 1887 and 1912 and Second Old River forming between 1842 and 1864, long after the Caddo left Crenshaw (Figure 5). In addition to maps, aerial photographs show the path of the river channel since the 1940s (Figure 6) and the areas which have since been eroded by the river. Parts of the Crenshaw site and any satellite sites that might have existed along these meander paths would have been destroyed by the river to the south (Second Old River), northwest (First Old River), and east (modern Red River channel).

Historic maps, aerial photography, and lidar depict a more complete river meander sequence with their estimated ages (Figures 3, 5, 6, 7, 8). Figure 8 includes depressions of partially infilled abandoned channels (7 and 8) that were not recognized earlier by Pearson (1982). Thus, it shows additional areas that may have been destroyed by the river since the Caddo occupation at Crenshaw (Channel 7) and channels that may have been active or abandoned to form an oxbow lake at the time the Caddo occupied Crenshaw (Channels 7 and 8). Identification and relative ages of Channels 7 and 8 are based on their cross-cutting relationships and degree of fill evident on lidar, providing better time resolution than previous studies. A land survey in the 1840s, an 1864 drawing (see 1864

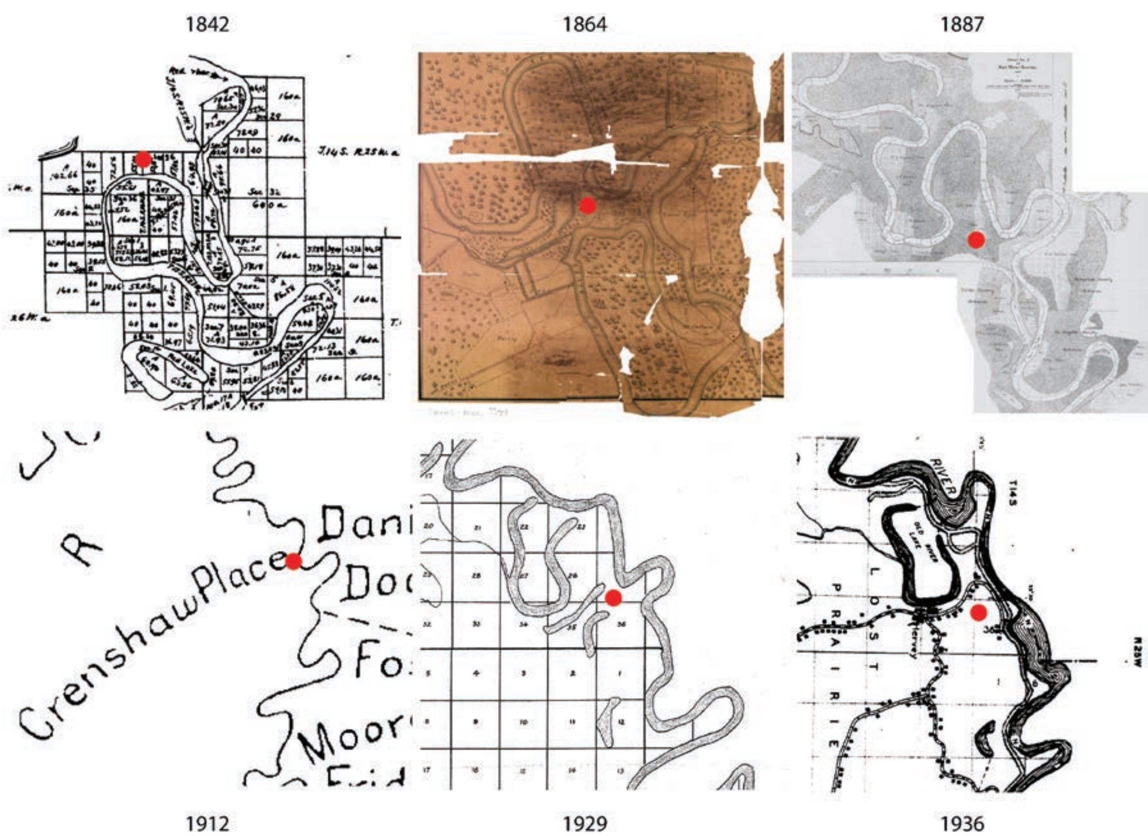

Figure 5. Location of Red River around Crenshaw in 1842 (Arkansas Commissioner of State Lands [COSL] 2000), 1864 (University of North Carolina Library 2009), 1887 (United States Engineer Department 1886), 1912 (Moore 1912), 1929 (Arkansas Highway and Transportation Department [AHTD] 2009), and 1936 (AHTD 2009). Position of Crenshaw shown in red.

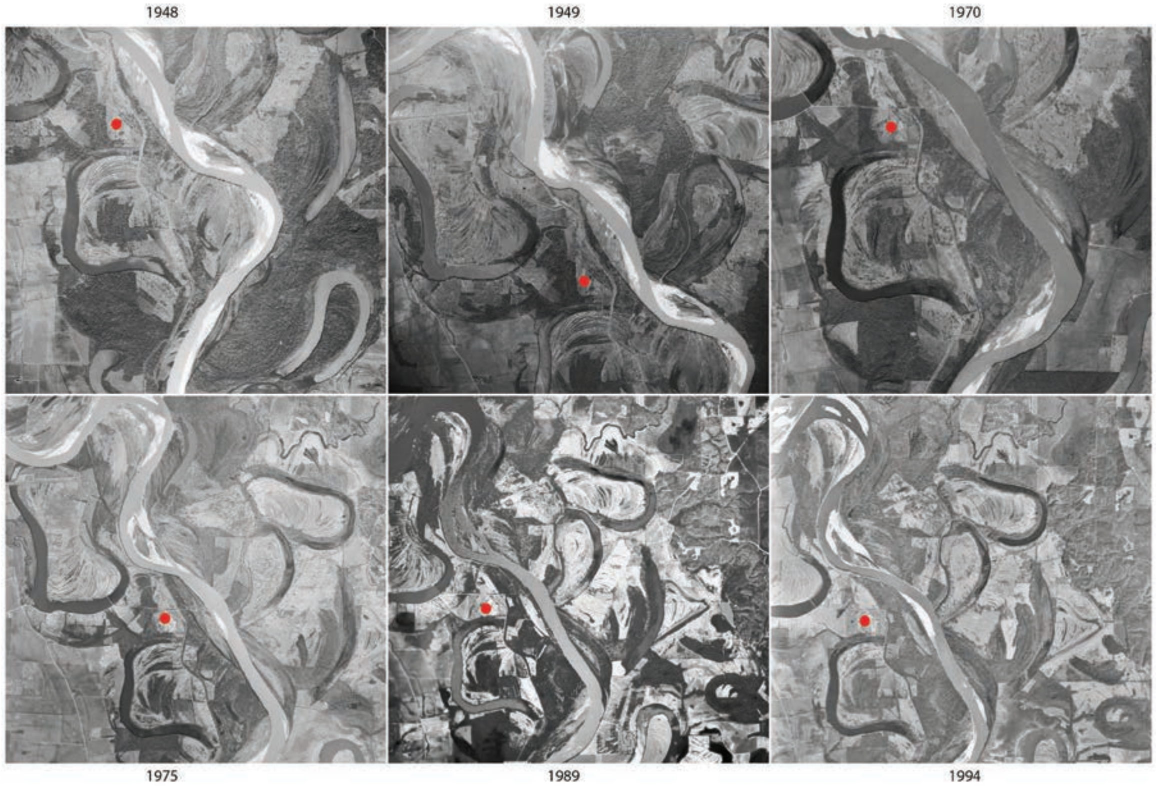

Figure 6. USGS(2009) aerial photographs around Crenshaw from 1948 to 1994. Position of Crenshaw shown in red.

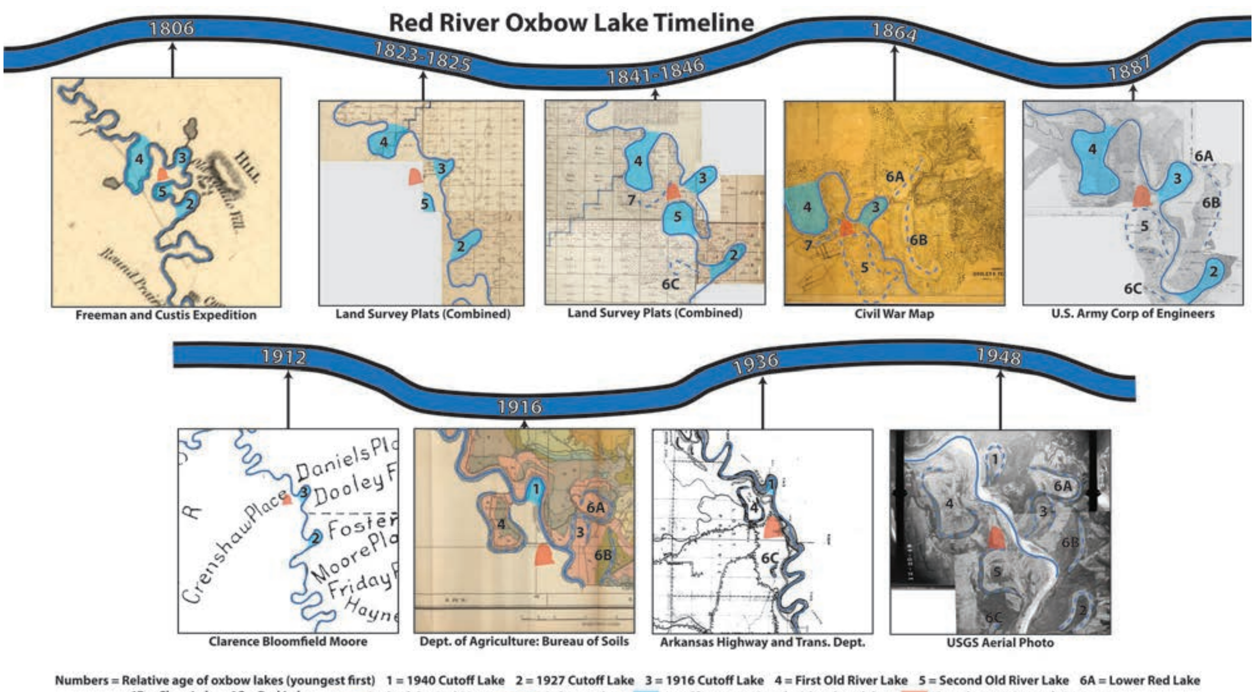

Figure 7. Maps used in fluvial sequencing include one from the Freeman and Custis Expedition in 1806 (Library of Congress 2020), plat maps (Arkansas COSL 2000), a Civil War map (United States National Archives and Records Administration 2020), USGS maps (United States Engineer Department 1886), C. B. Moore's map (Moore 1912), a 1916 map (United States Department of Agriculture [USDA] 1916), a 1936 map (AHTD 2009), and aerial photography (USGS 2009).

map in Figure 5 with lake west of Crenshaw), and an AHTD map from 1929 show the remnants of Channel 7 in the form of an oxbow lake. An on-site survey of the location confirmed the identification of Channels 7 and 8.

The eastern and northeastern edge of the Caddo occupation is unknown because the river left a fluvial landform east of the site and west of the current channel that will not contain any ancient cultural material. Based on historic records of channel movements, most areas east of the constructed levee have been destroyed as marked by Sequence 1 (Figure 8).

The current river has also eroded the eastern side of the meander belt at the latitude of Crenshaw as recently as the 1960's (Sequence 1, Figure 8). Pearson (1982) also concluded that most of the floodplain east of the river near Crenshaw is young, precluding satellite sites from being found east of the river (Sequences 3, 6A, and 6B). However, there are small portions that have been undisturbed by historic meandering as evidenced by 3HE12 and 3HE14, two mounds that may have Fourche Maline or Caddo cultural affiliations. Both these sites lie in a thin sliver of land that appears to have preserved between three separate meanders that approached it from the north, west, and south. Just east of these sites, the uplands begin (see Figure 4). Unfortunately, the mound at 3HE14 was bulldozed into its own borrow pit to level the land. A portion of the mound may still be intact beneath the surface. Also, on the east side of the Red River and to the north of Crenshaw, another prehistoric mound has been preserved that has an unknown cultural affiliation (3HE17).

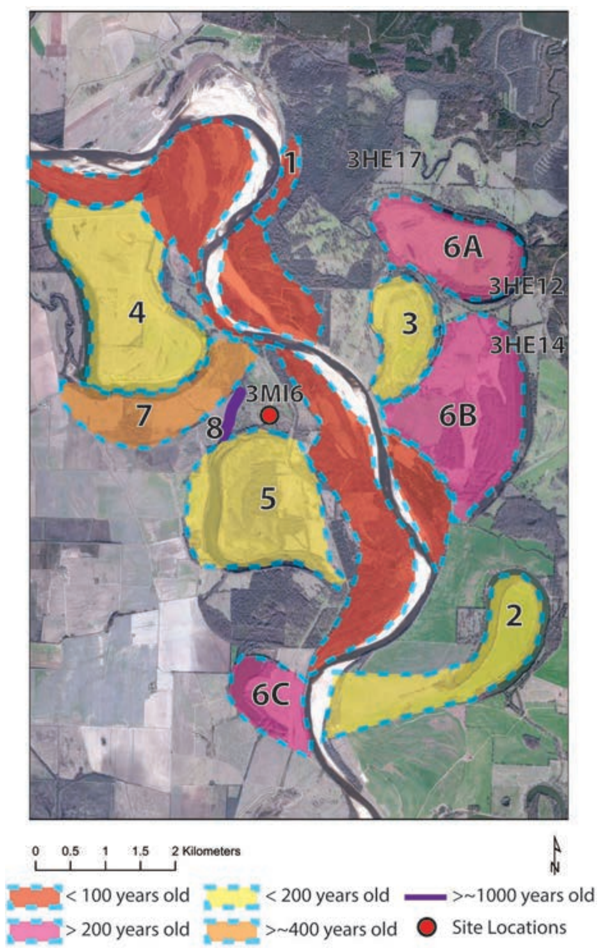

Figure 8. Fluvial sequence around Crenshaw (3MI6) from the most recent (1) to the oldest (8). It is unclear which is older or younger in Sequence 6. 3HE12, 3HE14, and 3HE17 are depicted in a general area to protect site locations.

Some information can be gleaned about an important potential historic site to the east. The Freeman and Custis Expedition map (see Figure 7) from 1806 shows an "Old Caddo Village" just to the east of Crenshaw and the Red River (Flores 1986; Library of Congress 2020). If the mapping is accurate, it may still yet exist on the landscape. Though significant areas east of Crenshaw have been eroded by the migration of the river since the site's occupation, there appears to have been relatively little destruction east of the active river channel since 1806.

On the northern portion of Crenshaw, no obvious meander landforms are present and thus the site could extend north to the modern channel. Samuelsen's (2020) geophysical study found many archaeological features in this area. A shovel test survey in this area by Kelley and Coxe (1998) found midden and Caddo artifacts. Extension of the site to the north is also supported by a rim sherd found in Crenshaw Core 17, buried within a midden at 172 cm below the surface (Figures 3, 9).

To the northwest of Crenshaw, the meander that created First Old River (and probably Channel 7) destroyed any archaeological material that may have been present (see Figure 8). Outside of Channel 7, beneath its associated natural levee, archaeological material and features may be deeply buried and difficult to identify with geophysical equipment, particularly closer to the channel.

The western edge of the site is known to continue at least to the vicinity of Core 37 where

Figure 9. A rim sherd found in core 17 on the northern portion of Crenshaw. It was located 172 cm below the surface in midden and has a design consistent with the Middle Caddo period (Ann Early, personal communication 2014).

geophysical anomalies were found (Samuelsen 2020). There have also been reports in the Arkansas Archeological Survey site files of Fourche Maline material in fence postholes about 15 m north of Core 33. This area also includes a depression that likely marks an abandoned channel and/or a borrow pit for Mound A (see Discussion). In either case, the site extended west of this depression.

South of the site is Second Old River (Channel 5). If the ancient site had extended in this direction, it would have been eroded. This leaves a narrow area just southwest of the site that may still contain cultural material, though artifacts may be buried by natural levee deposits of Channel 5 (see Figure 8). Investigations in this area might provide information about the original extent of the ancient site in that direction and about the possibility of any satellite sites. The likelihood of occupation farther to the southwest and west is limited by backswamp.

In summary, based on the positions of channels on the landscape, the areas most likely to contain possible extensions of the presently known site boundaries and/or the preservation of satellite sites are west, southwest, and north of the site as presently mapped. There are many ancient sites recorded in these areas, attesting to these landforms' relatively old age. Some of these have been tentatively designated as Fourche Maline or Caddo sites. The undisturbed area north of Crenshaw could also contain satellite sites, and the site itself continues north for an unknown distance. A clear delineation between "sites" may not exist if farmsteads were constructed close to the mound center. Clearly, there are significant portions of the site that have not been eroded and have been buried by younger river sediment, making identification of an exact site boundary difficult, but the preserved site is estimated to be 60-75 hectares in size.

Cores

Two depressions west of Mound A suggest the presence of at least one abandoned channel near the site (Figure 10). The eastern depression is deep and wide and may be, in part, a borrow pit for Mound A. The western depression (near Core 35) is considerably narrower and less continuous. These two depressions merge to the south, near the location of Core 3. A core transect showing subsurface stratigraphy is used to assess whether two channels are present, to measure channel size, and to assess its relationship to the ancient Caddo occupation (Figure 11).

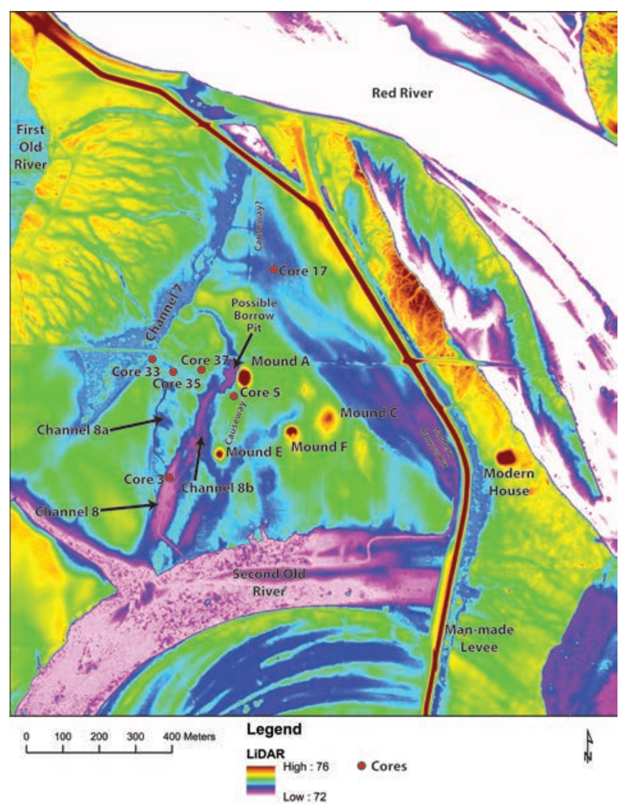

Figure 10. Lidar map of Crenshaw showing the locations of interpreted Channels 7, 8a, and 8b.

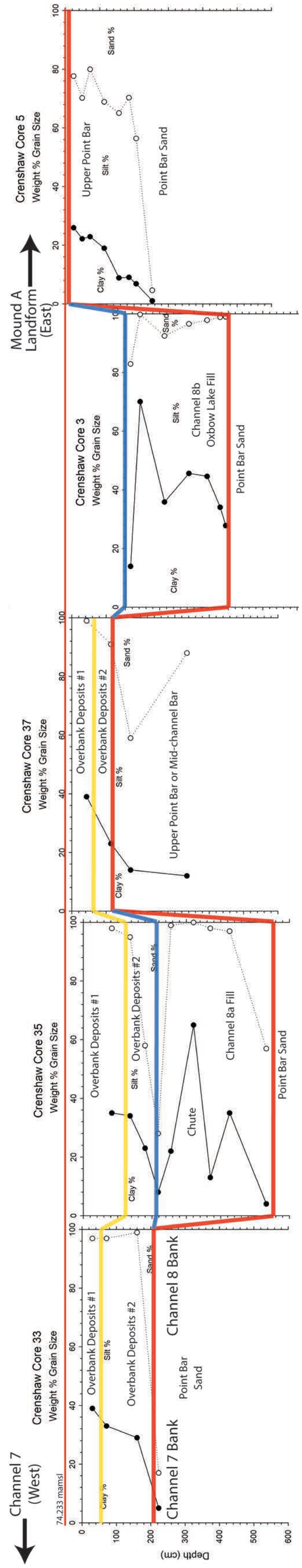

Figure 11. Profile of the five cores showing plots of grain size analysis. Complete description of the cores is in the Appendix. The surface of each core is represented by the top line for each plot, corrected for elevation based on lidar. The horizontal axis is not to scale. Lines represent boundaries of depositional units as interpreted from core descriptions and grain size analyses. The yellow line is the base of overbank #1 deposit and the top of overbank #2 deposit with a soil developed in it. The blue line represents the top of channel-fill deposits with a soil developed in the fill at Core 35. The red line represents the top of point-bar or mid-channel bar sand. Core 35 is in Channel 8a and Core 3 is in Channel 8b (see Figure 10). Overbank deposits are likely derived from Channels 7 and 4, to the west of the transect.

At the west end of the transect, Core 33 is tentatively interpreted to be positioned in a narrow area between abandoned Channels 7 and 8a (see Figure 10). Two clay- and silt-rich overbank deposits are present (see Figure 11). The upper 0.6 m-thick overbank deposit #1 is separated from the lower 1.6 m-thick overbank deposit #2 by a buried soil, indicating that there was a hiatus in deposition after the lower overbank sediment was deposited. The lower fine-grained deposit has an abrupt boundary with an underlying loamy sand, which caused core refusal. This sand is interpreted as a point-bar deposit from a channel position older than both Channels 7 and 8a. No buried soil is preserved within the sand, suggesting either erosion or that no appreciable time lapsed before the sand was buried by overbank sediment. Because the top of the sand is lower in elevation than areas to the east, erosion along a cut bank of Channel 7 is the preferred interpretation.

Located approximately 70 m east of Core 33, Core 35 exposes a 5.6 m-deep channel infilled with thick, bedded channel fill and subsequently two surficial overbank deposits, forming a land surface with only a slight depression (see Figure 10). As in Core 33, two silt and clay overbank deposits are separated by a buried soil. The surficial overbank unit is thicker compared to that in Core 33 to the west and Core 37 to the east, nearly filling the swale present in the buried land surface. In contrast, the lower overbank deposit #2 thins to the east and is intermediate in thickness compared to Cores 33 and 37, respectively east and west of this location. It is also separated from the underlying channel fill by a buried soil. Most of the fill is silt and clay but some sandy beds are present. Within the fill, boundaries are commonly abrupt, a few of the beds have internal bedding and no buried soils separate the beds. This stratigraphy attests to active channel fill where water and sediment frequently flowed through the channel at low velocities and vegetation was negligible to absent until the channel was mostly filled. At the core base, a sandy loam, which represents the base of the channel, caused refusal.

Core 37, between the subtle depression at Core 35 (Channel 8a) and the large surface depression (Channel 8b) (see Figure 10) is interpreted to be a sand bar between Channels 8a and 8b (see Figure 11). Like the locations to the west, accumulation of the upper

1.2 m of silt and clay also occurred in two episodes, as shown by a buried soil between the two units. The upper overbank deposit #1 thins a little over this topographic high compared to the adjacent swale (core 35). The lower overbank deposit #2, the thinnest identifiable exposure identified along the transect, is only 0.3 m thick. The upper 2.5 m of the underlying bar are sandy beds, most of which vary from sand to loam with only one 0.2 m-thick silt loam bed. All bedding boundaries are abrupt indicating that aggradation of this bar surface was continuous. The upper bar surface emerged above the water level and began to accumulate 0.3 m of clay (the lower overbank deposit #2) so slowly that a soil formed in this fine-grained deposit. Final aggradation of 0.9 m of overbank #1 silt and clay buried the exposed bar and became the present land surface.

Core 3, located within the large depression shown in the lidar data and easily visible on site, had to be taken south of the transect to position the drill rig within the depression. In addition, the location of Core 3 was sufficiently far from Mound A where it is unlikely the Caddo obtained sediments for mound building and thus the sample has not been disturbed.

The sediment exposed in Crenshaw Core 3 is nearly three meters of oxbow-lake clay and silt fill in a former cutoff channel of the Red River, Channel 8. This fill likely overlies an unsampled channel sand that caused core refusal. The fill is dominantly clay and silt that generally fines upward (see Figure 11). Very low amounts of very fine sand indicate low-energy deposition. Small changes in texture suggest that there may have been slight changes in sediment influx as the filling proceeded and a 0.1 m thick silt bed at 0.1 to 0.2 m depth is interpreted to have accumulated during a flood event of higher energy than the depositional events resulting in most of the oxbow lake fill.

Unlike the bedded channel fill at Core 35, the channel fill in Core 37 includes root pores, redoximorphic features, cutans, and no evident bedding within the horizons, indicating that the lake was not deep, that vegetation grew as the lake infilled, and bedding, if any had been present, was mostly or completely disrupted by bioturbation. Preservation of charcoal at 0.9 m depth indicates that oxidation was limited. The final fill was the slow accumulation of clay with soil development. At the surface is a thin blanket of historic debris of burned wood and ash.

At the east end of the transect, Crenshaw Core 5 is sampled about 40 m east of the large linear depression (Channel 8b), and approximately 30 m southwest of Mound A (see Figure 10), on the same landform as the mound. Core 5 exposed sand with 2.1 m of upward fining, bedded, loamy sediment. The lower 1 m of overbank deposition is loam and silt loam, coarser grained than the overbank deposits in the remainder of the transect and is likely the uppermost part of the sand bar. The surface meter is an overthickened dark A horizon, also formed in loam and silt loam with microdebitage in the upper 0.7 m.

Discussion

Schambach (1996:Figure 5.2) proposed that an area immediately west of Mounds A and E (Channel 8) was the location of the Red River at the time of the Caddo or Fourche Maline occupation. There is a linear low spot on the landscape there, suggesting that it may be the location of a mostly filled oxbow lake. If this channel was active during occupation, it likely would be older than the oxbow lakes currently on the landscape (Channels 4, 5, and 7, as confirmed by the fluvial sequencing, see Figure 8), making it a possible location for the Red River during occupation. If it is a filled oxbow lake, in addition to the presence of a depression, large amounts of clay and silt should be present within the depression and sandy deposits should be present along the edges of the channel. During flood stages, oxbow lake fills accumulate as muddy floodwater slowly advances across the floodplain. As the flooding abates, the muddy stagnant floodwater remains within an oxbow lake or old channel and the silt and clay slowly settles out of suspension (Bridge 2003). In contrast, a point bar is formed by deposition of coarser sediments along the inner bank of the river as it migrates. The resulting ridge and swale topography is formed by sand as thick as the channel is deep. Therefore, the results from the Crenshaw Cores provide a means to test the hypothesis that the Red River existed west of the site during occupation and later avulsed to the east.

Geomorphology

A combination of lidar data, cores, historic maps, and excavation data establishes that four channels are present west of Mound A. Furthest to the west are Channels 4 and 7. Channel 4 is younger than the Caddo occupation. There remains a possibility that Channel 7 was active at the end of the Caddo occupation. Both Channels 4 and 7 have clear boundaries (see Figure 10) and may be responsible for some overbank sediment on the western portion of the site. Two channels west of Crenshaw have been mostly filled (Channel 8a) or partially filled (Channel 8b). These channels can only be traced a short distance because they have been eroded to the south by Channel 5 and eroded or buried to the north so that they are not visible on the landscape. The two channels merge to the south and are interpreted to be part of the same meander bend. Channel 8a appears to be the furthest west position of the Red River for this meander bend as it migrated to the west. While this meander bend was still active, a chute channel cutoff formed on the meander bend and the main channel shifted from Channel 8a to Channel 8b. After this shift, Channel 8a experienced limited flow and filled with bedded sediment as Channel 8b became dominant. Eventually permanent abandonment of the inner channel, (Channel 8b), by a neck cutoff somewhere to the east allowed the Channel 8b to become an oxbow lake and slowly fill. Some of this fill was utilized by the ancient Fourche Maline or Caddo for the adjacent mound construction (Mound A).

Channel morphology can be reconstructed using lidar and stratigraphy along the core transect. Fill in Channel 8a is at least 5.7 m deep and may have been up to 140 m wide. Based on both the lidar data and the sediment exposed in Core 3, Channel 8b is estimated to have been approximately 5 m deep and has been more than half filled with oxbow-lake silt and clay. The base of Channel 8a is at least 3 m below the present abandoned channel surface and the present topographic depression is approximately 2 m below the surrounding surface. Based on lidar data (see Figure 10) Channel 8b is at least 80 m wide. Both Channels 8a and 8b are narrower than the modern channel or recently well-preserved abandoned channels that are 250 to 325 m wide. It is possible that the bar at Core 35, between Channels 8a and 8b is a mid-channel bar separating two branches of the channel and the outer channel died as the inner channel became dominant. The full width of Channel 8 in that case would be approximately 220 m, more consistent with the modern channel width.

The surface on which Mound A is constructed is an upper point bar of Channel 8a and 8b. Some fine-grained overbank sediment has been infiltrated into the upper point bar loam and the surface aggraded slightly to form a thick A horizon. It does not appear that any significant amount of the two overbank deposits across the western portion of the transect extended east of Channel 8b. It is likely that Channel 8b was an oxbow lake at the time Crenshaw was occupied and that the lake was simply a poorly drained depression by the time Mound A was constructed with some of the channel fill used for the construction of the mound. Initial occupation of Crenshaw may have occurred when 8b was an active channel, but this is impossible to ascertain with the present data.

Archaeological Importance

An unexpected, but important result of the lidar data analysis is that the depression west of Mound A, previously thought to be a borrow pit, is most certainly purposeful landscape modification by the ancient Caddo (Figure 12). Beyond the construction of the mounds, the causeway, and the borrow pits, the Caddo or the antecedent Fourche Maline appear to have modified the edge of the oxbow lake (Channel 8b) that existed west of Mound A. The rectilinear patterns in this area do not form natural geomorphological features. Instead, it appears that this area was modified to have rectilinear topographic features while also being used to construct Mound A. These results are also supported by a rectangular anomaly with a central area of high magnetism in geophysical data corresponding to the elevated rectangular area (see Samuelsen 2020:Figure 5.19). While the shape is likely the result of taking sediment for the construction of the mound and causeway, the resulting rectilinear pattern represents the Caddo purposefully excavating from specific areas. All of this landscape modification shows that the Caddo were not just inhabitants in their environment but were actively modifying their environment according to their ritual or ecological designs.

The Caddos' modification of and use of this area as a borrow pit also suggests that this was an abandoned channel and not an active channel at the

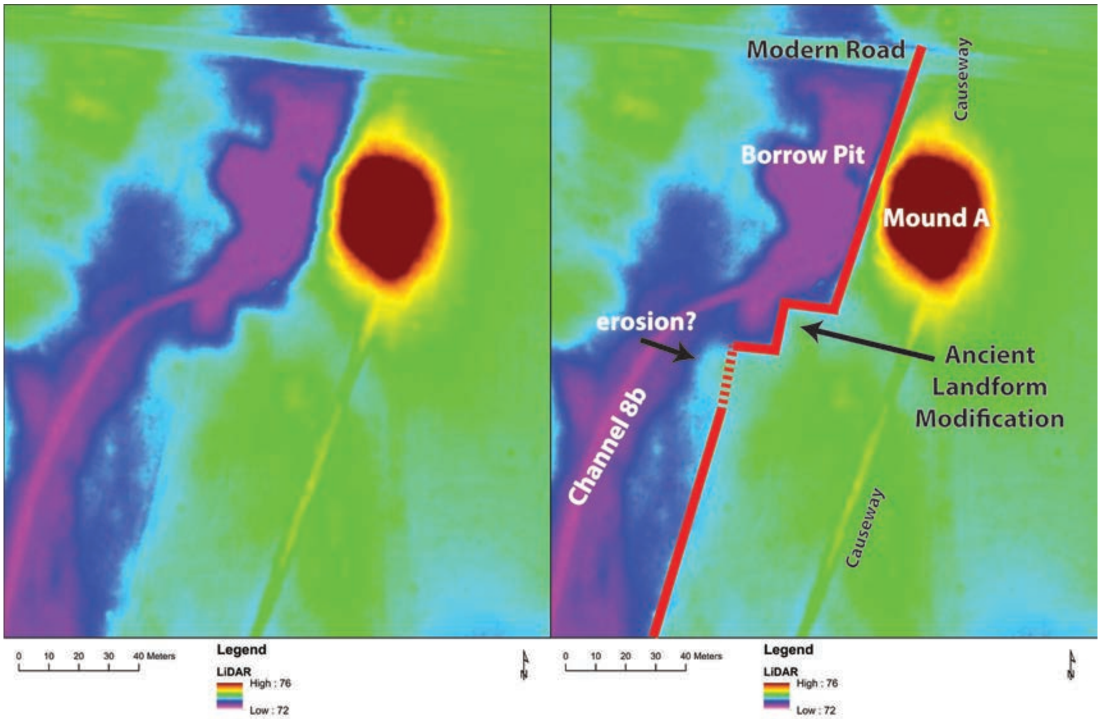

Figure 12. Rectilinear patterns are shown in the lidar at Crenshaw reflecting ancient landform modification by the Caddo. This modification of the landscape is in addition to the already apparent construction of the mounds, causeway, and borrow areas.

time it was modified and Mound A was constructed. This is because this modified shape would not have withstood the water movements of an active channel. In addition, the borrow is deeper here than the area around it, suggesting that channel fill was excavated after the channel was abandoned by the river. The human activity in Crenshaw Core 5 and a geophysical survey (Samuelsen 2020) both confirm the use of this area by the ancient inhabitants. The top meter of Crenshaw Core 5 on the adjacent point-bar landform is darkened by human activity. The overthickened A horizon and bioturbation of this horizon made it difficult to find stratigraphic boundaries and suggest minor accretion of the surface during human occupation. In addition, quartz appeared in the gravel fraction of the uppermost sample, suggesting the presence of microdebitage in the area and therefore human occupational debris.

Because Mound A and the causeway are on a point bar of Channel 8, it is impossible for them to have existed prior to its migration across the site. Therefore, Channel 8 migrated to the west before it was cut off, forming an oxbow lake. It was only long after the point bar was formed, the channel was cut off, and fill accumulated in the lake that the Caddo constructed Mound A and the causeway from the adjacent borrow pit material of channel fill. This also implies that they similarly constructed Mound E after the oxbow lake formed. While Schambach's (1996) suggestion that the river channel was active when the Fourche Maline or Caddo occupied the site could still be true for the earliest portion of the occupation, it appears that, at least when the Caddo were constructing mounds, the active channel of the Red River was to the east.

Schambach's (1996) map also shows the water flowing eastward in Second Old River's location. However, it is clear from the historic records and lidar data that Second Old River was later in time and that the water flowed westward. This is important because it means that unknown portions of the site were likely destroyed as Second Old River migrated across the southern portions of Crenshaw's landform. The current understanding of the site needs to consider the possibility that part of the originally inhabited landform was destroyed prior to Moore's (1912) site map. Crenshaw's skull and mandible cemetery and an ash bed structure were excavated near Second Old River (Samuelsen 2009), indicating that ancient Caddo occupation extended up to the current location of the oxbow lake. This is also confirmed by a geophysical survey (Samuelsen 2010). Therefore, our understanding of the timing of occupation and ritual/domestic use of the site may be distorted by preservation factors.

Previous studies (Kelley and Coxe 1998; Samuelsen 2020) and multiple pieces of information analyzed in this study all point to the Crenshaw site extending north, probably to the recently constructed levee. This provides some support for the hypothesis that the northern linear raised feature is an ancient causeway rather than an artifact of an old fence line, because the northernmost areas are deeply buried by younger river sediment in Core 17 (see Figures 9, 10). A study of the geomorphology and subsurface stratigraphy of this northern area would be beneficial to understanding the Caddos' use of this portion of the site.

Conclusions

The information obtained from the fluvial sequencing analysis, lidar data analysis, and analysis of the core transect adds to the geomorphological knowledge of the area as previously explored by Guccione and colleagues (Guccione 2008; Guccione et al. 1998) and Pearson (1982). There is little evidence that any Holocene Red River meanders exist west of Channels 8a and 8b, and the First (Channels 4 and 7) and Second Old Rivers (Channel 5). This bolsters Guccione's (2008:Figure 7) definition of the boundary between the meander belt and backswamp in this area.

The cores provide environmental information about the area during the last few hundred years. That the area was prone to flooding is indicated by the amount of surficial clay and silt deposited in the western portion of the transect (Cores 33, 35, and 37). This matches well with our understanding of prior Red River positions because Channels 7 and 4 west and northwest of the site probably caused much of this flooding. Flooding was less frequent on the higher elevation point bars of abandoned Channels 8a and 8b where the mounds and causeway are located and no identifiable overbank deposit is present. The presence of one or more oxbow lakes likely provided the Caddo with fresh water and fish. The absence of an actively meandering channel at the location allowed preservation of at least part of the site.

This study tests the hypothesis that the low areas on the west side of the Crenshaw site (Channels 8a and 8b) were abandoned Red River channels at the time the Caddo occupied the site. The results suggest that Channel 8a filled relatively rapidly as some water flowed through, but Channel 8b was abandoned and became an oxbow lake. Partial filling of that lake occurred before the Caddo constructed mounds. Based on this information, the Red River has been east of the preserved portion of the site since the time of the construction of Mound A. It is possible, if not likely, that significant portions of the occupied landform were subsequently destroyed by the migration of Second Old River. Although less clear, Channel 7 may have also eroded portions of the site to the northwest. Other areas of the site to the north are buried by overbank sediment. Therefore, our present understanding of the size, population, and timing of occupation may be distorted by preservation factors.

The analysis shows that the Caddo actively engaged with their environment. Beyond building mounds, they modified landforms according to their designs. The combination of the rectilinear modification of the landscape along the abandoned channel and the construction of causeways shows that the ancient Caddo at Crenshaw designed landscape features unrivaled elsewhere in the Caddo Area and much of the Southeast. This information, combined with the unusual ritual activity and extensive occupation documented by archaeology and geophysics (Jackson et al. 2012; Samuelsen 2020; Schambach 1996), shows that Crenshaw was a location that had great significance to the ancient Caddo.

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Appendix.

Table 1. Miller County, Arkansas, Crenshaw Core 3.

Location: 1.85 km west of the Red River, 0.29 km north of the Second Old River Lake **Elevation:** 73.67 m LIDAR	**County and State:** Miller County, Arkansas **Soil:** Mapped as Latanier Clay **Described by:** John Samuelsen

Geomorphic Position: Cutoff channel of the Red River, west of the First Old River and north of Second Old River lakes.

Elevation (m)	Depth (cm)	Thickness (cm)	Horizon	Parent Material	Description
73.67	0-3	3	Ap	Ash Deposit	Black (7.5YR 2.5/1) silt loam; granular structure; many fine roots; common fine root pores; abrupt boundary; abundant organics; burnt vegetation in area.
73.64	3-11	8	2Ap	Oxbow-Lake Deposit	Very dark grayish brown (10YR 3/2) clay; strong brown (7.5YR 5/6) concentrated few medium distinct redoximorphic features; moderate medium subangular blocky structure; common fine roots; common fine root pores; abrupt boundary; very firm as if fused.
73.56	11-19	8	2C1	Oxbow-Lake Deposit	Strong brown (7.5YR 4/6) silt loam; weak medium subangular blocky structure; few fine roots; abrupt boundary.
73.48	19-173	154	2C2	Oxbow-Lake Deposit	Strong brown (7.5YR 4/6) clay; brown (7.5YR 4/2) depleted common coarse distinct redoximorphic features; strong medium angular blocky structure; few medium roots; few fine root pores; common medium patchy cutans; gradual boundary.
71.94	173-266	93	2C3	Oxbow-Lake Deposit	Brown (7.5YR 4/3) silty clay; yellowish red (5YR 5/8) concentrated few fine faint redoximorphic features, dark gray (7.5 YR 4/1) along pressure faces; moderate medium angular blocky structure; few medium patchy cutans; indistinct bedding; abrupt boundary.
71.01	266-283	17	2C4	Oxbow-Lake Deposit	Brown (7.5YR 4/4) silty clay loam; moderate medium angular blocky structure; few fine root pores; few thin patchy cutans along root pores; clear boundary.
70.84 70.75	283-292+	9+	2C5	Oxbow Lake Deposit	Reddish brown (5YR 4/4) silt loam; minor masses of redoximorphic features around root pores; weak medium subangular blocky structure; few fine root pores. Refusal.

Table 2. Miller County, Arkansas, Crenshaw Core 5.

Location: 1.55 km west of the Red River, 0.46 km north of the Second Old River Lake
Elevation: 74.23 m LIDAR

Soil: Mapped as Severn Silt Loam
Described by: John Samuelsen

Geomorphic Position: Point bar of adjacent abandoned Red River Channel 8b, 66 m SSE of the Mound A center.

Elevation (m)	Depth (cm)	Thickness (cm)	Horizon	Parent Material	Description
74.23	0-66	66	A1	Upper Point Bar	Dark brown (7.5YR 3/3) silt loam; moderate medium subangular blocky structure; common fine roots; few fine root pores; gradual boundary.
73.57	66-100	34	A2	Upper Point Bar	Dark brown (7.5YR 3/4) loam; moderate medium subangular blocky structure; few fine roots; few fine root pores; gradual boundary.
73.23	100-130	30	C1	Upper Point Bar	Yellowish red (5YR 4/6) loam; weak coarse subangular blocky structure; few fine roots; common fine root pores; gradual boundary.
72.93	130-199	69	C2	Upper Point Bar	Yellowish red (5YR 5/8) silt loam; weak medium subangular blocky structure; few fine roots; few fine root pores; clear boundary.
72.24	199-209	10	C3	Upper Point Bar	Reddish yellow (5YR 6/8) silt loam; massive; abrupt boundary.
72.14 71.56	209-267+	58+	C4	Point Bar Deposit	Pink (5YR 7/4) sand; fine grading down to sand; bedded; single grain. Refusal.

Table 3. Miller County, Arkansas, Crenshaw Core 33.

Location: 0.82 km south of the Red River, 0.5 km southeast of First Old River Lake **Elevation:** 73.67 m (LIDAR)	**Soil:** Mapped as Severn Silt Loam, but more like Latanier Clay **Described by:** Justin Estep, Zach Asbury, Will Harmon
Geomorphic Position: Between abandoned Channels 7 and 8b	

Elevation (m)	Depth (cm)	Thickness (cm)	Horizon	Parent Material	Description
73.67	0-8	8	Ap	Overbank #1	Brown (7.5YR 4/3) silty clay loam; moderate medium subangular blocky structure; many fine roots; common fine root pores; abrupt boundary.
73.59	8-36	28	Bw1	Overbank #1	Brown (7.5YR 4/3) silty clay loam (clayey silt); moderate medium subangular blocky structure; few fine roots; common fine root pores; few thin continuous cutans; clear boundary.
73.31	36-60	24	Bw2	Overbank #1	Dark brown (7.5YR 3/4) silty clay loam; moderate medium subangular blocky structure; few fine roots; few fine root pores; common thin continuous cutans; clear boundary.
73.07	60-92	32	2Ab	Overbank #2	Very dark brown (7.5YR 3/3) silty clay loam (clayey silt); strong fine subangular blocky structure; few fine roots; common fine root pores.
72.75	92-116	24	2Bwb	Overbank #2	Dark brown (7.5YR 3/4) silty clay loam; moderate coarse subangular blocky structure; few fine roots; few fine root pores; few thin patchy cutans; clear boundary.
72.51	116-129	13	2BCb1	Overbank #2	Reddish Brown (5YR 4/4) silty clay loam; weak coarse subangular blocky structure; few fine root pores; gradual boundary.
72.38	129-168	39	2BCb2	Overbank #2	Yellowish red (5YR 4/6) silty clay loam (silt); weak coarse subangular blocky structure; few fine roots; few fine root pores; diffuse boundary.
71.99	168-216	48	2BCb3	Overbank #2	Yellowish red (5YR 4/6) silty clay loam; weak coarse subangular blocky structure; few fine roots; few fine root pores; few thin continuous cutans; abrupt boundary. (Silt)
71.51 - 71.38+	216-229+	13+	3C	Point bar sand	Yellowish red (5YR 5/8) loamy sand (silty sand); massive. Refusal.

Table 4. Miller County, Arkansas, Crenshaw Core 35.

Location: 600 m (0.6 km) east of First Old River Lake, 510 m (0.51 km) north of Second Old River Lake, 830 m (0.83 km) south of Red River (94 paces southeast of Core 30, 33.1 m southeast of Core 31 and 67.1 m northwest of Core 34)
Elevation: 73.65 m LIDAR

Soil: Mapped as Latanier Clay
Described by: Minella Majenu, Dale Solomon, Dustin Ply

Geomorphic Position: Slight depression between abandoned Channels 7 and 8b

Elevation (m)	Depth (cm)	Thickness (cm)	Horizon	Parent Material	Description
73.65	0-15	15	Ap	Overbank #1	Very dark brown (7.5YR 2.5/3) silty clay loam; moderate medium subangular blocky structure; many fine roots; few fine root pores; abrupt boundary.
73.50	15-46	31	Bw1	Overbank #1	Brown (7.5YR 4/4) silty clay loam; weak medium subangular blocky structure; few fine roots; few fine root pores; clear boundary.
73.19	46-109	63	Bw2	Overbank #1	Brown (7.5YR 4/3) silty clay loam (clayey silt); strong medium subangular blocky structure; few fine roots; few fine root pores; common medium continuous stress cutans; clear boundary.
72.56	109-122	13	C	Overbank #1	Strong brown (7.5YR 4/6) silty clay loam; weak medium subangular blocky structure; few coarse roots; bioturbation of underlying unit; abrupt boundary.
72.43	122-166	44	2Ab	Overbank #2	Very dark brown (7.5YR 2.5/2) silty clay loam (clayey silt); moderate medium subangular blocky structure; few fine roots; few fine root pores; common thin continuous stress cutans; gradual boundary.
71.99	166-193	27	2Bwb	Overbank #2	Reddish brown (5YR 4/4) loam (mud); weak medium subangular blocky structure; few fine roots; few fine root pores; clear boundary.
71.72	193-231	38	2C	Overbank #2	Yellowish red (5YR 4/6) sandy loam (silty sand); massive; abrupt boundary.
71.34	231-272	41	3Ab	Chute-channel fill	Dark brown (7.5YR 3/3) silty clay; moderate medium subangular blocky structure; few fine roots; few fine root pores; few thin continuous stress cutans; gradual boundary.
70.93	272-305	33	3Bwb1	Chute-channel fill	Yellowish red (5YR 4/6) silty clay; few medium distinct manganese depletions; weak medium subangular blocky structure; few fine root pores; few thin patchy stress cutans; abrupt boundary.
70.60	305-349	44	3Bwb2	Chute-channel fill	Reddish brown (5YR 4/4) clay (silty clay); common medium distinct manganese depletions around root pores; weak coarse subangular blocky structure; few fine root pores; many thick continuous stress cutans; abrupt boundary.

70.16	349-379	30	3C1	Chute-channel fill	Yellowish red (5YR 4/6) silt loam (silt); few fine distinct grayish-black disseminated organic depletions around root pores; bedded; few fine roots; few fine root pores; secondary calcium carbonate concretions; abrupt boundary.
69.86	379-396	17	3C2	Chute-channel fill	Yellowish red (5YR 4/6) silty clay loam; secondary calcium carbonate concretions; few fine distinct gray-black disseminated organic depletions around root pores; weak medium subangular blocky structure; few fine roots; few fine root pores; few thin patchy cutans; secondary $CaCO_3$ concretions; abrupt boundary.
69.69	396-405	9	3C3	Chute-channel fill	Yellowish red (5YR 4/6) silt; few fine distinct depletions around roots pores; massive; few fine root pores; secondary $CaCO_3$ concretions; abrupt boundary.
69.60	405-438	33	3C4	Chute-channel fill	Yellowish red (5YR 4/6) silty clay loam (clayey silt); few fine distinct depletions; weak medium subangular blocky structure; few fine root pores; few thin patchy cutans; secondary $CaCO_3$ concretions; abrupt boundary.
69.27	438-446	8	3C5	Chute-channel fill	Yellowish red (5YR 4/6) silt; massive; few fine root pores; secondary $CaCO_3$ concretions; abrupt boundary.
69.19	446-466	20	3C6	Chute-channel fill	Yellowish red (5YR 4/6) loam; bedded; secondary $CaCO_3$ concretions; abrupt boundary.
68.99	466-472	6	3C7	Chute-channel fill	Reddish brown (5YR 4/4) silty clay; few fine distinct depletions; weak medium subangular blocky structure; secondary $CaCO_3$ concretions; abrupt boundary.
68.93	472-539	67	3C8	Chute-channel fill	Yellowish red (5YR 5/6) silt loam (sandy silt); (medium sand from 515-527 cm depth); massive; abrupt boundary.
68.26	539-550	11	3C9	Chute-channel fill	Reddish brown (5YR 4/4) silt loam; few medium distinct manganese depletions; bedded; secondary $CaCO_3$ concretions; abrupt boundary.
68.15	550-558	8	3C10	Chute-channel fill	Reddish brown (5YR 4/4) clay; common fine faint depletions; weak coarse subangular blocky structure; secondary $CaCO_3$ concretions; abrupt boundary.
68.07	558-574+	16+	4C11	Point bar Sand	Yellowish red (5YR 4/6) sandy loam; massive; tiny calcium carbonate concretions.
67.91					Refusal

Table 5. Miller County, Arkansas, Crenshaw Core 37.

Location: 0.80 km south of the Red River, 0.54 km southeast of First Old River Lake

Elevation: 74.04 m LIDAR

Soil: Mapped as Latanier Clay

Described by: Julia Heydenreich, Calvin Johnson and John Wohlford

Geomorphic Position: Slight hummock west of buried Channel 8b

Elevation (m)	Depth (cm)	Thickness (cm)	Horizon	Parent Material	Description
74.04	0-12	12	Ap	Overbank #1	Dark brown (7.5YR 3/2) silty clay loam; weak medium subangular blocky structure; common fine roots; few fine root pores; organic and charcoal fragments present; clear boundary.
73.92	12-66	54	Bw1	Overbank #1	Reddish brown (5YR 4/3) silty clay loam (clayey silt); moderate medium subangular blocky structure; few fine roots; few fine root pores; few thin patchy stress cutans; clear boundary.
73.38	66-93	27	2Ab1	Overbank #2	Dusky red (2.5YR 3/3) silty clay; moderate medium subangular blocky structure; few fine roots; few fine root pores; few thin patchy cutans, organic fragments present; clear boundary.
73.11	93-124	31	2Ab2	Overbank #2	Dark reddish brown (5YR 3/2) clay; strong medium subangular blocky structure; few fine roots; common fine root pores; common thin continuous cutans; bioturbation (burrows filled with underlying material); gradual boundary.
72.80	124-157	33	3Bwb1	Upper Point Bar Sand	Brown (7.5YR 4/3) loam with fine to very fine sand; weak coarse subangular blocky structure; few fine roots; few fine root pores; clear boundary.
72.47	157-196	39	3Bwb2	Upper Point Bar Sand	Strong brown (7.5YR 4/6) loam with fine to very fine sand (sandy silt); weak coarse subangular blocky structure; few fine roots; few fine root pores; clear boundary.
72.08	196-209	13	3Bwb3	Upper Point Bar Sand	Strong brown (7.5YR 4/6) loamy sand; weak coarse subangular blocky structure; few fine root pores; abrupt boundary.
71.95	209-225	16	3C1	Upper Point Bar Sand	Strong brown (7.5YR 4/6) loamy sand; massive; few fine roots; few fine root pores; abrupt boundary.
71.79	225-306	81	3C2	Upper Point Bar Sand	Strong brown (7.5YR 4/6) sandy loam with very fine sand; weak coarse subangular blocky structure; few fine root pores; abrupt boundary.

70.98	306-322	16	3C3	Upper Point Bar Sand	Strong brown (7.5YR 4/6) loamy sand; massive; few fine root pores; abrupt boundary.
70.82	322-343	21	3C4	Upper Point Bar Sand	Brown (7.5YR 4/4) silt loam (sandy silt); massive; few fine root pores; few fine secondary $CaCO_3$ concretions; abrupt boundary.
70.61	343-368	25	3C5	Point Bar Sand	Reddish yellow (7.5YR 6/6) sand; massive; few fine secondary $CaCO_3$ concretions; abrupt boundary.
70.30	368-374+	6+	3C6	Point Bar Sand	Yellowish red (5YR 4/6) sandy loam; massive; few fine root pores; few fine secondary $CaCO_3$ concretions. No refusal.