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The Kiwanis Site: A Multi-Method Geophysical Approach to Investigating Mound Features

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A Multi-Method Geophysical Approach to Investigating Mound Features

By

Luke Burds

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This thesis has been examined and approved by the following members of the student's committee.

Dr. Ron Schirmer

Dr. Phil Larson

Dr. Garry Running

Dr. Harry Jol

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Abstract

Subtle mound-like landforms can be genetically ambiguous features within a landscape. A variety of geomorphological and anthropological processes can result in these equifinal forms being difficult to interpret. Being able to reliably and noninvasively differentiate them is important for legal as well as cultural and spiritual reasons. A suite of non-invasive geophysical methods were thus used on mounds at the Kiwanis site in western Wisconsin in order to determine if culturally diagnostic indicators could be recorded in geophysical data. Genesis of these mounds is ambiguous given the presence of aeolian landforms in immediate proximity. As a control, the same geophysical methods are applied to previously identified anthropogenic mounds at the nearby Belle Creek site in eastern Minnesota. Data from both locations indicate increases in electrical resistivity and range in magnetic gradient within or near the mounds, suggesting an anthropogenic origin. 500 MHz GPR data show strong, semi-continuous horizontal reflections at depth within each mound. These reflections dip away from the apex of each mound in all directions. Since this is inconsistent with predominant southerly winds responsible for aeolian deposition at Kiwanis, we interpret these to represent grainflow during construction of the mound or during post-construction diffusion. A rectangular reflection measuring 2 x 4 x 0.5 m is visible in the center of the Kiwanis mound and cannot be explained via aeolian processes. We hypothesize this to be remnants of a mortuary feature due to its shape and orientation. We conclude that the Belle Creek and Kiwanis site mounds are similar in genesis, and internal anomalies at Kiwanis further support an anthropogenic origin. The methods applied here have proven effective as a non-invasive approach to identifying anthropogenic mounds and should be considered in future studies of ambiguous mound-like forms.

Contents

1.0 Introduction

The purpose of this Master's thesis is to investigate the origin of hemispherical features resembling Native American burial mounds at the Kiwanis site in Western Wisconsin in the Lower Chippewa River Valley (LCRV). Mound-like features can be ambiguous in origin due to a variety of geomorphological and anthropomorphic processes resulting in equifinal forms. It is imperative that mound sites of Native American origin remain undisturbed out of respect for the dead and to preserve the sanctity of their graves given their immense cultural significance as a place of burial and spiritual connection for Native Americans. Indeed, mounds formed through anthropogenic means are protected from disturbance by laws, such as NAGPRA (1990) and Wisconsin state statute 157.70 (1985). These reasons make the internal study of mounds a delicate process, requiring noninvasive techniques for examining mound forms. Geophysical techniques that do not require the disturbance of soil to study the physical properties of the subsurface meet this criterion, and can thus be used to identify subsurface anomalies consistent with human modification. While such methods have been employed in many archeological investigations requiring a similar degree of sensitivity (e.g., Nobes 1999, Dobbs et al. 2003, Matais et al. 2006, Juerges et al. 2010, Johnson 2015, Nero 2016, Beck et al. 2018, Burds et al. 2018), examinations of the utility of such methods on mounds specifically in the Midwest are limited (Mier et al. 1995, Mathys 1997, Jol and Running 2002, Viavattine et al. 2002, Kaufmann 2005, Whittaker and Storey 2008, Green 2020).

This project examines the utility of noninvasive, geophysical methods including ground penetrating radar (GPR), electrical resistivity, and magnetometry to study questions regarding the origins of the Kiwanis site. The same methods employed at the Kiwanis site are applied to a mound site of verified cultural origin known as the Belle Creek site to provide comparative baseline data. Similarities between the two sites can serve to better inform whether the mounds at the Kiwanis site are cultural or natural in origin. Future investigations of mound features will benefit from this study through understanding the utility of geophysics when examining suspected mound sites. Chapter 1 of this thesis provides a basic understanding of the Kiwanis site, earthen mounds, and geophysical methods. Chapter 2 is a discussion of the methods used in the examination of the mound features at the Kiwanis and Belle Creek sites. Results are discussed in Chapter 3. Chapter 4 is a discussion of what the results suggest in relation to the genesis of the mounds. Chapter 5 then concludes with the determination of the origins of the Kiwanis mounds as well as suggestions for future work at the site and similar investigations.

1.1 Kiwanis Site Description and Discovery

The Kiwanis site is located approximately 13.7 kilometers west of the city of Eau Claire along the LCRV (Figure 1). The site was discovered in the Spring of 2017 during investigations of Light Detection and Range (LiDAR) imagery of Eau Claire and Dunn counties. The study, conducted by Schaetzl et. al. (2017), primarily focused on features formed through aeolian deposition. Included in these are parabolic dunes in cliff-top position, leading researchers to note the northern edge of a cutbank meander along the LCRV due to the presence of three large parabolic dunes. Hemispherical and linear mound shaped features were also visible in LiDAR imagery directly northeast of the parabolic dunes and are the focus of this study (Figure 2). The shapes of the mound features are consistent with Native American burial mounds (Birmingham and Eisenberg 2000), prompting researchers to notify local archeological officials of their existence. However, a counter argument was raised that the features could be the result of aeolian processes and modern agricultural practices, leading to the necessity of visiting the site in person. Ground truthing of the features in the Spring of 2018 confirmed their existence and deemed it necessary to further investigate their origin through the use of noninvasive techniques.

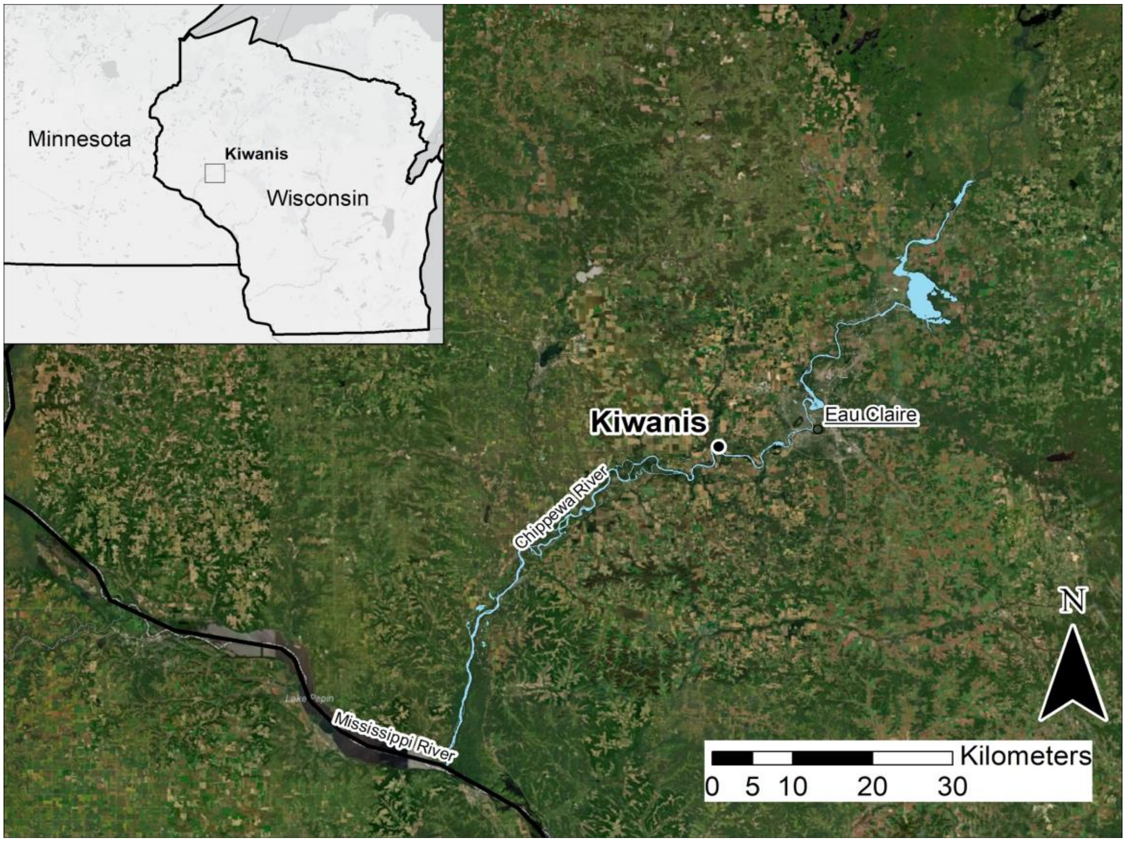

Figure 1: Map of the location of the Kiwanis site in western Wisconsin along the Chippewa River. The site is located roughly 13.7km west of the city of Eau Claire within the Lower Chippewa River Valley.

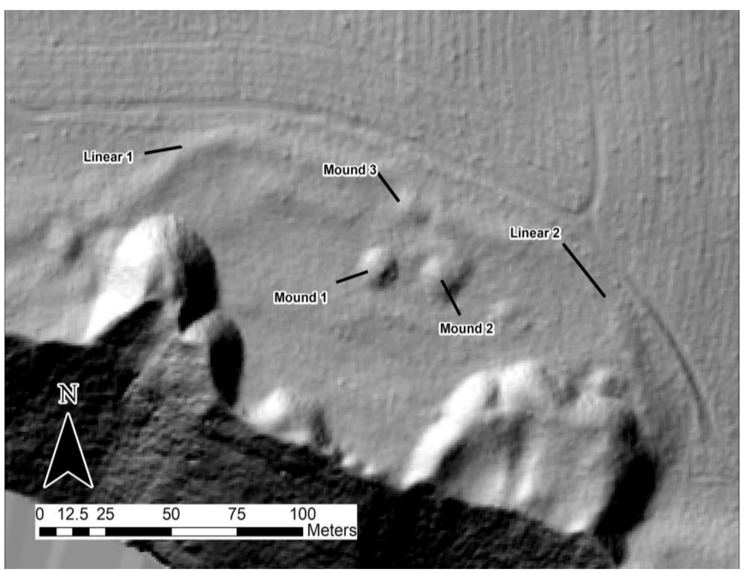

Figure 2: LiDAR image of the Kiwanis site with each of the mound features labeled and are the focus of this study. The mounds were discovered by examining LiDAR images collected along the Lower Chippewa River Valley to study parabolic dunes in clifftop position. Clifftop dunes are visible in this image, as the large parabolic shaped features just west and southeast of mounds 1 and 2.

1.2 Kiwanis Site Geomorphic Setting

The possibility that the mounds at the Kiwanis site are natural in origin requires an understanding of the geomorphic setting within which the mounds are found in order to test this hypothesis. The Kiwanis site falls within the geographic locale described as the LCRV (Figure 3). The LCRV falls within the greater Chippewa River watershed that comprises roughly 25,000km^2, two-thirds of which was glaciated during the Late Wisconsinan (Faulkner et al. 2016). The LCRV comprises the lower one-third of this region and is primarily controlled by bedrock consisting of Cambrian quartzose sandstones (Faulkner et al. 2016). The LCRV experienced periods of aggradation and incision by glacial meltwater streams as the Chippewa and Superior lobes ablated (Faulkner et al. 2016). These events are recorded in the broad flatlands capping dense layers of glaciofluvial sediments incised upon by the Chippewa River and its tributaries, as well as the numerous terraces left by incision events initiated by base level fall in the Upper Mississippi River Valley (UMRV) (Faulkner et al. 2016). Understanding the stratigraphic sequence of deposition present at the site is imperative to identifying disparate features in geophysical surveys, including the base of the mound features. Further, the time when the mound features formed can be inferred based upon dates related to the formation of surrounding features. These include the Wissota Terrace, a sand sheet that is directly beneath the mounds at the Kiwanis site, and nearby cliff-top dunes.

1.2.1 Wissota Terrace

The Wissota terrace is the oldest glacio-fluvial feature upon which the Kiwanis site is situated (Figure 4). The terrace extends from the terminal moraine of the Chippewa Lobe in the north to the Savanna terrace of the UMRV in the south (Faulkner et al. 2016). Two prominent incision events described by Faulkner et al. (2016) are responsible for the formation of the Wissota terrace. The first of these occurred roughly 18 to 16 thousand years ago and stabilized along the Kiwanis site sometime around 12.9ka (Faulkner et al. 2016) according to OSL ages collected by Loope et al. (2012), dropping the base level of the LCRV roughly 15m. A second incision event occurred roughly 13.9 to 13.1 ka according to OSL ages collected by Lepper et al. (2013). This event was likely caused by outburst floods along the southern outlet of glacial Lake Agassiz

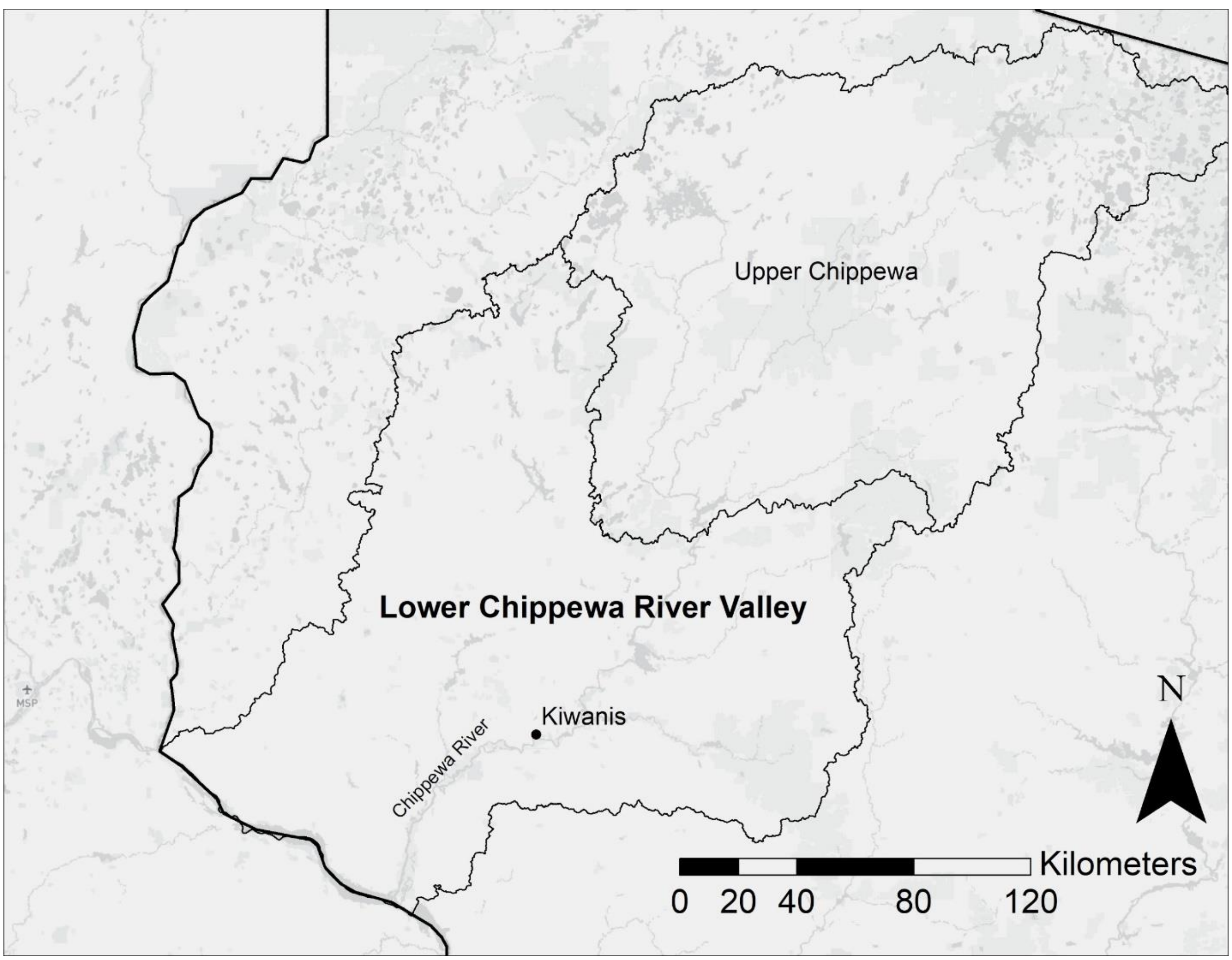

Figure 3: Map of the Chippewa River Watershed created by Faulkner et al. (2016). The LCRV falls below the dotted line demarcating the extent of the last glacial maximum. This region was the focus of studies of parabolic dunes in clifftop position that led to the discovery of the Kiwanis site.

along Glacial River Warren, which lowered the base of the Mississippi River level roughly 50m below the Savanna terrace (Faulkner et al. 2016). However, this incision event did not reach the Kiwanis site until around 9 ka (Faulkner et al. 2016). The presence of the mound features upon this upland morphologic feature is consistent with distribution patterns of culturally constructed mounds throughout the Mississippi River Valley as they provide expansive viewscapes and are along prominent transportation routes (Birmingham and Eisenberg 2000, Arzigian and Stevenson 2003, Rosebrough 2010).

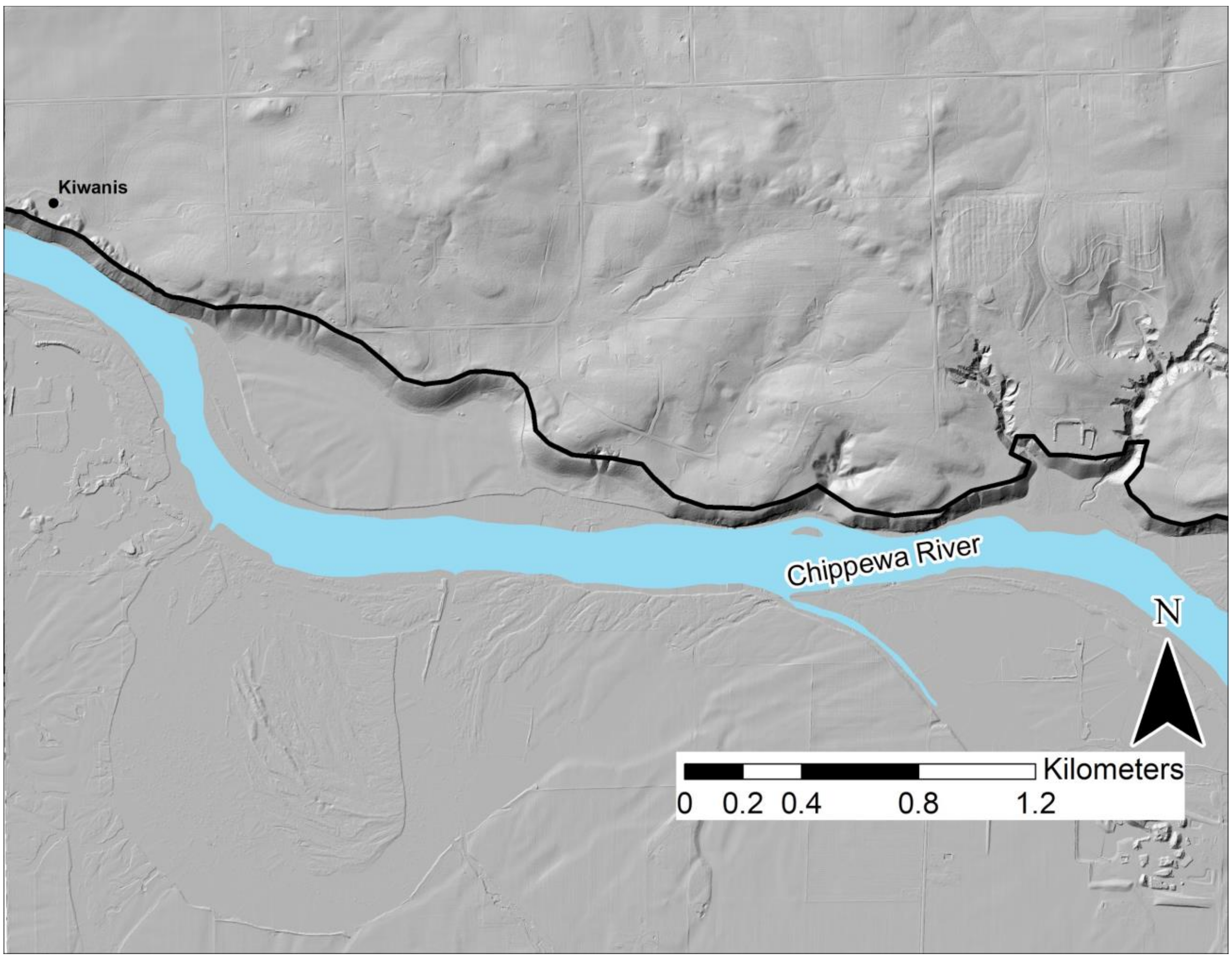

Figure 4: Map of the Wissota Terrace (in black) along the Lower Chippewa River Valley. The Wissota Terrace formed during two different incision events along the Chippewa River, the most recent occurring roughly 9ka according to OSL data collected from the feature.

1.2.2 Sand Sheets

A thin (<1.5m) deposit of fine to loamy sand is located atop the Wissota terrace and is interpreted as a sand sheet. Sand sheets are found upon the highest terraces within the LCRV and have been observed in ground penetrating radar and soil core analyses conducted throughout the LCRV (Faulkner et al. 2016, Shaetzl et al. 2017, Millett 2019). Soil samples collected at sites adjacent to the Kiwanis site containing sand sheets by Faulkner et al. (2016) and Schatzel et al. (2017) indicate these layers are distinct in texture when compared to the glaciofluvial sands of the Wissota terrace, consisting typically of fine sand, loamy fine sand, and loamy sand. The deposition of the sand sheet within the LCRV is suggested to have occurred during the end of the last glacial maximum as incision along the LCRV exposed fine grained sediments along channel escarpments to wind regimes capable of entraining them and depositing them upland. OSL dates collected by Millett (2019) at the Kiwanis site substantiate these claims, suggesting deposition occurred around 9.6 ka, coinciding with the approximate time incision was occurring along the LCRV in this region. The delineation of this feature within geophysical data is crucial in defining the base of the mound feature.

1.2.3 Cliff-Top Dunes

Above the sand sheet layer and adjacent to the mound features at the Kiwanis site are prominent parabolic dunes adjacent to the Wissota terrace escarpment. These features are defined by Larson et al. (2008) as cliff-top dunes and consist of fine to gravelly sand (Millett 2019). The formation of cliff-top dunes along the terraces within the LCRV occur during periods of aridity (several years of lesser precipitation than the present) coupled with continued river erosion along terrace escarpments within the LCRV (Millett 2019). Wind regimes are compressed along exposed and unvegetated escarpments, increasing wind propensity to entrain exposed material. This material is then deposited atop terrace escarpments when wind velocity dissipates. Differing windflow dynamics at different locations along the escarpment lead to the development of the parabolic shape of the dunes. OSL dates from the cliff-top dunes at the Kiwanis site indicate either two periods of deposition or one continuous deposition event between .96 and .45 ka. This coincides with a period of increased aridity lasting from about 900 CE to 1300 CE defined as the Medieval Climatic Anomaly (Millett 2019). This event coincides with the period of cultural history known as the Late Woodland (500 CE to 1200 CE) (Birmingham and Eisenberg 2000, Arzigian and Stevenson 2003, Rosebrough 2010).

1.2.4 Kiwanis Mound Features

The hemispherical and linear features at the Kiwanis site are directly northeast of the parabolic dunes and atop the sand sheet and Wissota Terrace (Figure 2). The size of the linear features and close proximity of all of the mounds to the aeolian features at the site would seem to indicate the features are burial mounds associated with the Middle and Late Woodland periods. However, the counter argument raised that the features could be the result of aeolian or biogeomorphic processes and modern agricultural practices necessitates their further investigation.

Aeolian features known as dome dunes (Ritley and Odontuya 2004, Narteau et al. 2017) can mimic the form of hemispherical mounds. Dome dunes are described as hemispherical in shape with no unidirectional dipping strata, known as slip faces, occurring in areas with low sediment availability. Further, they typically occur in dome dune fields containing multiple hemispherical dunes all sharing similar morphology and coexisting with barchan and linear dunes (Narteau et al. 2017).

Additionally, mounds known as Mima Mounds constructed, possibly by burrowing animals such as gophers, have been documented in Minnesota and Wisconsin that also share a similar morphology to Middle and Late Woodland burial mounds. These mounds are described as being void of stratigraphy and occurring within large mound fields containing hundreds to thousands of mounds at a time (Washburn 1988, Johnson and Burnham 2012, Gabet et al 2014).

If not prehistoric Native American in origin, the linear features at the site could still be the result of cultural practices. Modern agricultural techniques that involve removing or flattening of the topsoil can lead to the formation of linear ridges called field edge pushes. While these features can range in size depending on the extent of preparation of the agricultural field, it is unlikely they would be more than 1.5m wide as this would require extensive modification of the landscape. Further, these features appear to run perfectly parallel to the edge of the field they come from.

If it is determined a natural model of deposition does not explain the formation of the mounds at the Kiwanis site and the linear features there are not the result of agricultural practices, the mounds at the Kiwanis site can be deemed to be burial mounds associated with the Middle or Late Woodland periods. The Kiwanis site falls within what is defined as the Eau Claire subsection developed by Rosebrough (2010). Using an adapted system of ecological units established by Albert (1995) and Keys et al. (1995), Rosebrough defines the Eau Claire Subsection as being situated in the Northeastern portion of the Driftless Area ecological unit. This area consists primarily of tributary streams that empty into the Mississippi and Wisconsin rivers and incorporate land within Dunn, Pepin, Chippewa, Eau Claire, Buffalo, Trempealeau, Jackson, La Crosse, Monroe, Juneau, and Sauk counties. Few mound sites have been identified in this region, the exceptions being small clusters in southern Trempealeau County, southern Juneau County, and northwestern Sauk County (Rosebrough 2010). Yet, habitation sites do exist within this region (e.g., Hurley 1975, Barth 1983), along with areas significant for resource acquisition, such as Silver Mound near Alma Center, Wisconsin (Hurley 1975). In the North-Central portion of this region, surveys conducted by Barth (1983) note the presence of cultural material from the Late Woodland period at six sites due to the discovery of associated pottery (Barth 1983).

1.3 Early Mound Building

The first instances of mound construction for the purpose of burial are not specifically a Middle or Late Woodland phenomenon. Prior to the Woodland periods, in the Archaic period, between 8000 BCE to 1000 BCE (9950 BP to 2950 BP), cultural groups along the eastern coast of North America in modern-day Labrador began to bury their dead covered in crushed hematite, known as red ochre, as far back as 5600 BCE (7550 BP) (Birmingham and Eisenberg 2000). The deceased individuals were then placed in low lying mound structures made primarily of rock. Archaic earth work sites have also been documented in the southeast United States in Louisiana and Florida (Saunders et al. 1994, Birmingham and Eisenberg 2000) such as Watson Brake (Saunders et al. 2005) and Poverty Point (Ortmann 2010) in Louisiana. Indeed, mound construction at Poverty Point in northern Louisiana was so extensive it resulted in the eventual construction of concentric linear mounds around 1200 BCE (3150 BP) (Figure 5) that surround an open plaza interpreted to be the first major trade center in North America (Birmingham nad Eisenberg 2000, Ortmann 2010). The practice of mound construction began appearing in the Ohio and Illinois river valleys during the Early Woodland period between about 1000 BCE

(2950 BP) to 100 BCE (2050 BP). The mix of already established cultural ideas of groups within this region and the practice of mound building formed what is known as the Adena complex in the region. Adena is not specifically associated with one cultural group, but a set of shared cultural components as a result of the long distance trade networks established by groups within this region. Mound construction during this time resulted in hemispherical and conical shaped mounds that were built overtop of subterranean burial chambers. Chambers were sometimes lined with wood or stone and contained the remains of a single, likely important individual. Evidence of this comes from the inclusion of exotic grave goods such as copper, silver, or mica, which suggests an increase in social complexity amongst Adena groups within the region.

Figure 5: National Parks Service artistic representation of the mounds at Poverty Point, LA. The mounds were constructed roughly 3510 years ago, making them one of the oldest mound sites in North America.

Complexity within Adena societies eventually morphed into what is described as the Hopewell complex during the beginnings of the Middle Woodland period around 200 BCE (2150 BP). Mound construction practices during this time included the construction of a crypt containing multiple individuals rather than a single person. This crypt would be used usually by a family or clan and would continue to fill with individuals over time until a large conical mound was constructed overtop (Birmingham and Eisenberg 2000, Arzigian and Stevenson 2003). Hopewell groups also continued to expand trade networks outside of the Illinois and Ohio river valleys, linking much of North America as far out as the Rocky Mountains to the west and forming an expansive trade network known as the Hopewell interaction sphere. It is likely this trade network was strengthened by the ceremony involved in the construction of a mound, as exotic grave goods that were buried with prominent individuals would have helped emphasize their status and increase demand and kept trade flowing throughout eastern North America (Birmingham and Eisenberg 2000, Arzigian and Stevenson 2003, Fagan 2005).

It is perhaps through these interactions with distant groups beginning in the Early and Middle Woodland periods that the practice of mound building made its way into the cultural identities of groups in central and southern Wisconsin. Burials in this region prior to the construction of mounds are associated with the Red Ochre complex. Similar to what was practiced by Archaic individuals in modern-day Labrador, individuals were covered with crushed hematite before internment. However, Archaic groups in the Wisconsin area interred their dead in ossuaries atop prominent features in the landscape such as knolls or hills (Birmingham and Eisenberg 2000) rather than the low lying stone mounds found in Labrador. However, Birmingham and Eisenberg (2000) suggest that it is likely that the first mounds were constructed towards the end of the Archaic, around 800 BCE (2750 BP). Fagan (2005) notes that this could be part of the reason for the later explosion of mound construction that occurred within the Middle and Late Woodland periods as mounds are similar in shape to such features and were likely being constructed around 700 years prior.

As the Archaic period gave way to the Early Woodland period in the Wisconsin area around 1000 BCE (2950 BP), so too was the Adena complex beginning to take shape in the Illinois and Ohio river valleys. Similarities exist between the sparse mound sites found in Wisconsin from this time with those constructed by the Adena complex to the east, suggesting a connection between the two regions. However, while mounds have been located in Wisconsin that date to these times, mound construction appears to have become more prominent a practice during the Middle Woodland period.

1.3.1 Middle Woodland Mound Building

The Middle Woodland period dates to around 100 BCE (2050 BP) to 500 CE (1450 BP) and is marked by large-scale trading and ceremonial systems, such as those exhibited by groups of the Hopewell complex (Birmingham and Eisenberg 2000, Arzigian and Stevenson 2003). This period saw a massive expansion of trade systems throughout the Midwest and beyond, evident by large quantities of artifacts and resources traded throughout the entirety of the continent east of the Rocky Mountains, including ideas pertaining to the construction and utility of earthworks (Birmingham and Eisenberg 2000). Mounds associated with this time period are found in groups or mound centers. These groups are small clusters of mounds, not all necessarily built at the same time, and are located within major drainage valleys leading into the Mississippi in the upper Midwest (Birmingham and Eisenberg 2000).

The morphologies of the mounds at the Kiwanis site are similar in shape to mounds constructed during this time within the southern half of Wisconsin, and into Minnesota, Iowa, and Illinois (Birmingham and Eisenberg 2000, Kaufmann 2005). Mounds constructed during this time were often large and hemispherical in shape, however instances of linear or effigy mounds, mounds shaped as animals or spiritual beings, also exist (Birmingham and Eisenberg 2000).

Excavations of mounds associated with the Middle Woodland conducted by the Public Museum of Milwaukee in the 1930s revealed they were constructed in a similar fashion to mounds associated with the Hopewell complex. Prior to mound construction, a rectangular crypt or ossuary would be dug and the remains of prominent individuals would be interred until the burial feature was filled. Following this, the burial features would be enclosed completely by wood, and then covered by earth (Birmingham and Eisenberg 2000). Basket loads of material that made up the mound fill were brought in and deposited until the mound reached the desired proportions with additional layers of material and the inclusion of secondary burials in subsequent years following the completion of construction. (Birmingham and Eisenberg 2000). Thus, given the shape of mounds within the Kiwanis site, it may be that such burial features exist within and could serve as an identifying factor for determining the genesis for the mounds if visible in geophysical surveys.

1.3.2 Late Woodland Mounds

The Late Woodland period is noted to begin around 500 CE (1450 BP) with the shift from the large Hopewell Complex trade relationships developed during the Middle Woodland period towards more regionally focused relationships (Birmingham and Eisenberg 2000). This was brought about by a shift in climate that led to warmer and wetter weather in the Midwest, a climate that is more conducive to the cultivation of maize. Maize crops thus became a staple of the diets of Late Woodland groups and an important economic commodity of local trade (Birmingham and Eisenberg 2000). This too meant groups could become more self-sufficient, allowing them to stay in a specific place for extended periods of time, leading to the development of year round villages. Pottery during this time also evolved to include more depictions of spiritual beings such as the Thunderer or long tailed water spirits. Similar depictions are found on pottery constructed during this time, and are oftentimes abstract rather than a full depiction of the being in question. For instance, chevron decorations that form the tail of upper world beings such as the Thunderer are found on pottery without their accompanying components. Further, these decorations are not specific to pottery and are found being depicted in other artifacts such as clay pipes, drawn in rock art, or reflected in mound assemblages (Birmingham and Eisenberg 2000).

Mound construction during this time was greatly accelerated compared to the Middle Woodland period with some 15,000 mounds recorded in Wisconsin alone. Mound construction also began to shift from being solely centered around the mouths of prominent rivers to being constructed at special economic, ritualistic, or social locations. Late Woodland groups constructed hemispherical and conical shaped mounds for internment like their Middle Woodland ancestors, though not as large as those constructed during the Middle Woodland. However, mound building during this time also saw a marked increase in effigy mound construction (Birmingham and Eisenberg 2000). Effigy mounds are mound features constructed in the shape of animals, such as birds, bears, or panthers, that represent spiritual beings from Late Woodland belief systems (Birmingham and Eisenberg 2000). Effigy mounds are usually found within small clusters of mounds like their Middle Woodland counterparts, consisting of the effigy mounds themselves along with hemispherical and linear mounds (Birmingham and Eisenberg 2000). Further, Late Woodland peoples sometimes constructed their earthen monuments around the hemispherical mounds from the Middle Woodland period, suggesting a shared cultural understanding (Birmingham and Eisenberg 2000).

Mounds constructed during the Late Woodland period were primarily used as burial locations, much like Middle Woodland mounds. Burials were primarily located near the center of the mound in hemispherical mounds or the head or the heart of effigy mounds (Birmingham and Eisenberg 2000). The burials have been found to either be located in pits below the mound, on the original surface of the ground before the mound was constructed, or within the mound fill itself (Birmingham and Eisenberg 2000). In addition to burials, assortments of rocks thought to be death ritual altars have also been found. It is exceedingly rare to find Late Woodland mounds without either burials or altars within them (Birmingham and Eisenberg 2000). Where the mounds from the Late Woodland differ most notably from those of the Middle Woodland, though, is their overall size and the amount and condition in which those who are buried are found. Middle Woodland mounds are often large hemispherical mounds, often larger than 2 meters in height and diameter while Late Woodland mounds are usually much lower to the ground (Birmingham and Eisenberg 2000). In terms of the burials within, Middle Woodland burials are thought to have initially consisted of crypts within which multiple burials were included over a period of time before the mound was constructed over top. Late Woodland mounds mostly only contain a single person, or a few people buried all at the same time (Birmingham and Eisenberg 2000). Additionally, the burials most often are found as bone bundles, suggesting that the deceased was not initially buried “in the flesh” upon death (Birmingham and Eisenberg 2000). Birmingham and Eisenberg (2000) suggest that rituals such as temporarily resting the corpse on a scaffold open to the elements prior to final burial in a mound were likely the reason for this. The status ascribed to those found in Late Woodland mounds is also significantly different, as reflected by the associated grave goods. Rather than the symbols of status commonly found in Middle Woodland mounds, grave goods were few and simple if included (Birmingham and Eisenberg 2000).

The area within which these mounds are most often found comprises over half of the southern part of Wisconsin and extends into small portions of Illinois, Iowa, and Minnesota. Similar to Middle Woodland mounds, Late Woodland mounds are found in localized clusters, most commonly in high locations, such as bluffs or terraces that overlook rivers, streams, and wetland areas. Spatial analyses of the distribution of Late Woodland mounds suggests that the reason they were built in these areas is the rich availability of seasonal food resources found near them (Goldstein 1995, Arzigian and Stevenson 2003, Kaufmann 2005, Rosebrough 2010). For locations that fall out of this area, spiritual connections have been inferred. In the cases where mounds have been built in low ground settings such as near springs, it has been hypothesized that the reasoning behind this is the connection to the "Lower World" (Birmingham and Eisenberg 2000).

1.3.3 Effigy Mounds Meanings

Throughout the area where effigy mounds are found, they are most often interpreted to represent aspects of the Upper or Lower Worlds, which figure prominently in Native American belief systems. The Lower World is represented, in part, by water while the Upper World is associated with the sky. Many of the effigy mounds built during the Late Woodland period are thought to represent these two spiritual worlds depending on their shape. In terms of the Lowerworld, the primary mounds shapes associated with water are those said to be in the shape of panthers, turtles, or lizards (Birmingham and Eisenberg 2000). Evidence of this comes from direct consultation with elders of the Ho-Chunk community who notified early archeologists that the long-tailed "panther" mounds were representations of water spirits (Stout 1910 and Brown 1927 in Birmingham and Eisenberg 2000). Further evidence of this connection is provided by spatial analysis through which it has been shown that the majority of these "long-tailed" mounds are found near bodies of water. However, in addition to the water spirits, the earth itself is considered to be a part of the lower world. The effigy mounds primarily associated with this component of the lower world are usually considered to be in the shape of bears and buffalo (Birmingham and Eisenberg 2000). Bears are considered to be immensely spiritual beings as they are featured prominently in origin stories of many native groups. Occasionally there are also "lower world" mounds that represent wolves, foxes, along with deer and elk. However, some forms are much harder to discern and can only be subjectively interpreted due to their irregular shape (Birmingham and Eisenberg 2000).

Mounds that are associated with the upper world, the sky, are primarily found in the shapes of birds (Birmingham and Eisenberg 2000). In Wisconsin, these types of effigy mounds are the most common form found and are also some of the widest mounds ever constructed with wingspans stretching 100s of feet (Birmingham and Eisenberg 2000). The bird-shaped mounds are mostly considered to be associated with either the Thunderer or birds of prey, such as the hawk or falcon (Birmingham and Eisenberg 2000). Occasionally included are mounds thought to be in the form of waterfowl. The other mound forms associated with the upper world are those of the "bird-men". These mounds, initially thought to simply be bird mounds with exaggerated bifurcated tails, are anthropomorphic forms usually consisting of human torsos with bird-like heads (Birmingham and Eisenberg 2000). Due to their association with the upper world, these mounds are most commonly found in high places, such as bluffs and terraces.

While the upper world and lower world mound forms aid in explaining the shapes of the majority of effigy mounds associated with the Late Woodland period, there were still hemispherical and linear mounds constructed during this time. The symbolism of hemispherical and linear mounds is much more obscure, yet some, such as Hall (1993) and Smith (1999), suggest that these also represent the dichotomy between the upper and lower world. The linear mounds, in particular, are thought primarily to represent water serpents. Being associated with water, the linear mounds are thus thought to be associated with the lower world. The hemispherical mounds, on the other hand, are thought to represent the "bodies of the upper world birds" (Hall 1993). Again, though, these interpretations of the symbolism of hemispherical and linear mounds from the Late Woodland are not nearly as clear (Birmingham and Eisenberg 2000).

The role of mounds constructed during the Late Woodland period played within the societies they were constructed by was likely more than territorial markers like those constructed during the Middle Woodland. This is due to instances where mounds were not constructed along the highest points of river mouths, instead being constructed in a variety of social, economic, and ritualistic locations such as lowland springs or along high ridges. For example, mounds representing lower world spirits have been found near springs that represent the renewal of life as they bubble up to the surface. However, this practice is not exclusive to the lower world, as upper world mounds on spots in the landscape have also been observed in locations close to the migratory pattern of birds (Birmingham and Eisenberg 2000). It is not outside of reason, then, that instances of landscape changes associated with upper world beings would result in the construction of effigy mounds in the vicinity where they occur.

1.3.4 Variation of Mound Structure

Mound forms and location of their construction is various and so too is their internal stratigraphy. Due to the fact that mounds found throughout Wisconsin, Minnesota, Illinois, and Iowa were built over a long period of time by many different cultural groups, it holds true that the internal structure of individual mounds will be just as variable. The internal structure of mounds include components such as mound fill, original ground surface location, and structural elements such as prepared surfaces and large slabs of stone. While not all of these components may be adequately discernible for viable interpretation, a general understanding of their variation aids in interpretation as distinctly cultural in origin as opposed to being deposited naturally.

Studies conducted by Van Nest et. al. in 2001 described a classification scheme for understanding the mound fill of Hopewell mounds consisting of loaded fills, massive fills, and stratiform fills (Van Nest et al. 2001). Loaded fills are those mounds that have been constructed in a heterogeneous fashion. Loaded fill mounds have distinct units of deposition and are most commonly associated with “primary mounds” (Van Nest et al. 2001). In such cases, it has been suggested that the cause of this mixing is from the process of basket loading or may have been a result of a thin A horizon in the fill source area at the time of mound construction (Arzigian and Stevenson 2003). Massive fills are mounds whose fill is generally homogeneous, suggesting they likely come from the same source with a thick A horizon. The final of these three, stratiform fills, are analogous in nature to the bedded and laminated deposits found in geomorphic deposits (Van Nest et. al. 2001). These, however, are the least common of the three. Additionally, there exists variation in the reliability of locating the original surface of the ground located below the mound. This can prove challenging, yet is meaningful when determining the depth of mound features (Arzigian and Stevenson 2003). Furthermore, when the original surface below the mound can be found, it provides evidence as to whether or not the mound under investigation was cultural in origin. In some instances, such as Smith’s excavation of the Schoen mound in 1941, the original surface before mound construction can be determined by the abrupt change in ground composition (Smith 1941). This has been most feasible in instances where the fill of the mound is much lighter in color than the nutrient-rich, dark topsoil. However, many instances have also occurred where the original surface is not identifiable. This was due to the topsoil matching that of the mound fill, suggesting that mound fill was gathered in close proximity to the mound during construction (Wilford 1962). In instances such as these, mound elevation was estimated by comparison with the surrounding surface elevation (Wilford 1962), or through the use of soil cores (Goltz 1986). In the case of soil cores, Goltz' method was to core across the mound along two transects using a small diameter soil probe. The layers showing the most significant increase in size across the transect could be determined to be the soil fill while those staying at a relatively uniform thickness could be deemed the original ground surface.

Additional variation exists in the common elements found within the mounds themselves. Elements such as prepared surfaces, clay lenses, slabs or boulders, charcoal, and bark are among these elements found during excavation and have been most common, though not consistently. Prepared surfaces have been found in mounds either at the original surface of the ground before mound construction or higher in the mound profile (Arzigian and Stevenson 2003). Most commonly, these surfaces are made of clay. Clay has also been found in individual lenses within mound structures. In one case in Minnesota described by Wilford (1950b in Arzigian and Stevenson 2003), clay layers were used to delineate two different burial groups within the same mound. The use of individual layers of clay within mound construction is not straight forward in interpretation. However, Van Nest et. al. (2001) suggest that the selection of clays of different colors may have a symbolic significance. In another instance, clay was found in the form of a ridge overtop of what Lewis (1896) described as burial chambers made from stone slabs. The inclusion of stones in the formation of burial chambers has also been documented in other instances, usually forming a cavity within which remains and grave goods are placed. However, slabs of stone have also been documented in mound exteriors, enveloping the mound (Wilford 1937).

Though mound variation is extensive, the stratigraphic nature of the mounds as well as if they contain burial features will be the primary way through which the origins of the mounds are determined. While mound fill may not be identical throughout all mounds within the Midwest, if the orientation of the mound fill is not consistent with the aeolian features surrounding the mounds nor what would be expected if they formed through bioturbation, a natural genesis may be disproved. Further, if anomalies exist within the mound that stand out highly from their surroundings and appear unnatural in shape, these could be the remnants of burial features in the mounds.

1.3.5 Variation in Burial Practices

The ways through which individuals were interred within mounds is just as variable as the construction of the mounds themselves. Arzigian and Stevenson (2003) discuss a variety of methods for both primary or secondary burials within mound features. Primary burials are those that are conducted prior to or during mound construction. These types of burials could include pit burials, stone vaults, crypts or cairns, or internment in the base of the mound without the construction of a burial feature. Of these types of primary burials, pit burials below the base of the mound and burials of individuals at the base of the mound without the construction of a burial feature are the most common (Arzigian and Stevenson 2003).

The remains of the individual are placed in the primary position, whether that be within a pit or simply placed on the surface at the base of where the mound will be constructed (Arzigian and Stevenson 2003). Remains within mound features have been recorded as being positioned towards the cardinal directions, the fetal position, bundled burials of bone remains, and cremated remains. Following their placement within the boundaries of where the mound will be built, mound fill is piled on top of the burial and constructed into the desired shape (Arzigian and Stevenson 2003). However, instances of multiple individuals buried within the same burial feature have also been recorded, such as instances where bundle burials are continuously added to stone crypts before the crypt is finally covered by mound fill.

Secondary burials are those that follow the construction process of the mound. Remains, often bone bundles, are interred in small pits dug in the side of the mound that are then covered over to preserve the shape of the mound (Arzigian and Stevenson 2003). This practise likely was the result of ensuring that family members or people close to the individuals in the primary burial remain close after death. However, neither secondary burials nor primary burials are found in all mound features constructed by Native American groups (Arzigian and Stevenson 2003). Yet, their inclusion within the mound features at Kiwanis would definitively prove their origins.

1.4 Geophysical Methods

The Native American Graves Protection and Repatriation Act (NAGPRA) of 1990 in part protects against the excavation of Native American burials due to their immense cultural significance as a place of burial and spiritual connection for Native Americans. Thus, noninvasive methods are utilized to study the mound-shaped features of the Kiwanis site with the purpose of examining their stratigraphy and determining whether or not anomalies exist within that could indicate they are cultural in origin.

1.4.1 Ground Penetrating Radar

GPR is a noninvasive geophysical technique that involves the examination of the dielectric properties of subsurface stratigraphy. Specifically, GPR is used to determine the arrangement and extent of sedimentary structures in the subsurface without the need for excavation (Bristow and Jol 2003). GPR data are collected by sending a central frequency of electromagnetic radiation into the subsurface. An initial amount of energy is sent into the subsurface and as it interacts with different materials, portions of this energy are then sent back to the surface and collected by the receiving antenna. The energy that is not reflected continues downwards into the subsurface until the amount of energy reflected becomes infinitesimally small or is completely absorbed by the subsurface (Johnston 2018).

GPR data are either collected linearly or within a grid. Data collected linearly provide two dimension images known as transects that are images of the subsurface viewed from the side that allow the viewer to interpret the orientation and depth of different stratigraphic horizons. If data are collected in a gridded format, readings between transects can be interpolated to produce a pseudo-3D, top down view of the surveyed area known as a depth slice. Depth slice data can be used to view the spatial extent of anomalous areas or different horizons. The antennae in both types of surveys are either sequentially placed or dragged along the surface of the area in question and electromagnetic waves are sent into the subsurface via the transmitting antenna. Reflections are recorded by the receiving antenna. These reflections are caused when the energy transmitted interacts with a contrast in dielectric constants of individual materials (Johnston 2018). All materials have a dielectric constant which is the ratio of energy that is able to transmit, while a portion of it is also reflected back. When a change in subsurface material occurs, for example, a fine, sandy stratum over a solid igneous bedrock, the degree to which their dielectric constants differ will be illustrated in GPR profiles by either a strong or weak reflection signature. Thus, rather than detecting different subsurface materials to a certain depth, GPR detects the boundaries between materials that contrast in dielectric constants.

1.4.2 Electrical Resistivity

Electrical Resistivity is another noninvasive, geophysical method that examines the ease at which electrical currents sent into the subsurface pass through it. The degree to which an electrical current will pass through the subsurface depends on a variety of parameters, such as the mineral type, water content, porosity of the subsurface material, and the degree of saturation (Loke 2004). These measurements can then be processed into 1D, 2D, and pseudo-3D formats to aid in determining the possible material that can be found below the ground. Of these methods, the 2D method is most commonly conducted due to its ability to provide insight into both the vertical and horizontal changes in subsurface composition (Loke 2004). Surveys are conducted in a grid format with two pairs of electrodes. The primary pair of these, the “current” electrodes, induce a current into the subsurface that is then picked up by a remote pair of electrodes. These electrodes are known as the “potential” electrodes and measure the ability for the current to pass through the subsurface (Samouëlian et al. 2005). When these readings are collected along the lines of a grid, the readings can be interpolated across space to visualize areas anomalous to their surroundings. In studies where electrical resistivity has been used for the location of clandestine graves, burial locations where bodies are not covered appear as areas of low resistivity (Matias et al. 2006, Nero et al. 2016). However, in instances where the grave has been covered, such as the body being surrounded by stone slabs, areas of high resistivity compared to the surrounding sediments have been collected (Terrell 1998, Neuhauser 2009). Electrical resistivity has additionally been used in the location of burials within mound structures, such as the Papadopoulos et al. (2010) study of tumuli in Ghana. Yet, while the use of electrical resistivity has produced promising results when utilized as the sole geophysical technique for the detection of uncharted graves, integration with other methods such as GPR have proved to be more encouraging (Hansen et al. 2014, Nobes 1999, Bevan 1991, Juerges et al. 2010).

1.4.3 Magnetometry

Magnetometry is yet another non-invasive geophysical technique that examines the magnetic properties of the subsurface that can detect prehistoric modifications made to the magnetic field given off by individual features through either induced or remanent magnetism (Kvamme 2006, Smekalova et al. 2008). Induced magnetism is the case of an object becoming magnetized through its interaction with the Earth's magnetic field. It is directly proportional to the degree of strength of Earth's magnetic field in the object's locale and the ability of the object to influence the field around it (Smekalova et al. 2008). This is known as magnetic susceptibility. This property aids the archeologist in determining areas of surface disturbance, as topsoil, subsoil, and bedrock will all vary in their magnetic susceptibility. Thus, in cases where ditches or pits have been dug and subsequently filled in with topsoil, the variations in magnetic susceptibility will be detectable. Remanent magnetism, on the other hand, is the magnetic property an object has in the absence of a magnetic field. This property can be modified in the presence of heat, either naturally or artificially induced. Iron, for example, comprises nearly 6% of the Earth's crust and is found in soils, clays, and rocks across the globe. In its natural state, iron is typically a weak magnetic compound. However, when heated in cooking or industrial processes, its magnetic field can become heightened and detectable with instruments sensitive to magnetic variation (Smekalova et al. 2008). Thus, in instances where fires have been created, such as hearths, in situ remnants will produce magnetic anomalies that are measurable.

1.4.4 Belle Creek

The described geophysical methods were additionally applied to the Belle Creek site located in Red Wing, Minnesota with the intention of examining the internal structure of a mound of known cultural origin for comparison with data collected at the Kiwanis site (Figure 5). The Belle Creek site is situated atop an outwash terrace along the Cannon River and was first recorded by T. H. Lewis in 1885 during his expeditions throughout Minnesota to document significant Native American sites. Lewis noted nearly 70 mounds at the site, some of which have since been bladed over for agricultural practices (Figure 6). Evidence of known cultural origin at the site comes from the looting of mounds that took place in the late 19th and early 20th centuries. The site was purchased by the Prairie Island Indian Community in 2019, leading to geophysical investigations being conducted in a 100m x 40m grid in the summer of 2020 for the development of a site management plan for the tribe. These studies as well as soil probes with a 1" Oakfield Apparatus Soil Probe indicated a gradual change in sediment of silt sized grains in the northern half of the survey area caused by mass-movement from the adjacent uplands, moving to sand sized grains in the southern half of the survey area. Within this southern half of the survey area existed two prominent, hemispherical mound features, the western of which being more defined in shape than the eastern. Given the similar sedimentological characteristics between this mound and the mounds at the Kiwanis site, coupled with the cultural nature of the site, the western mound in the survey area was selected to serve as the basis of comparative analyses between the Belle Creek site and the Kiwanis site.

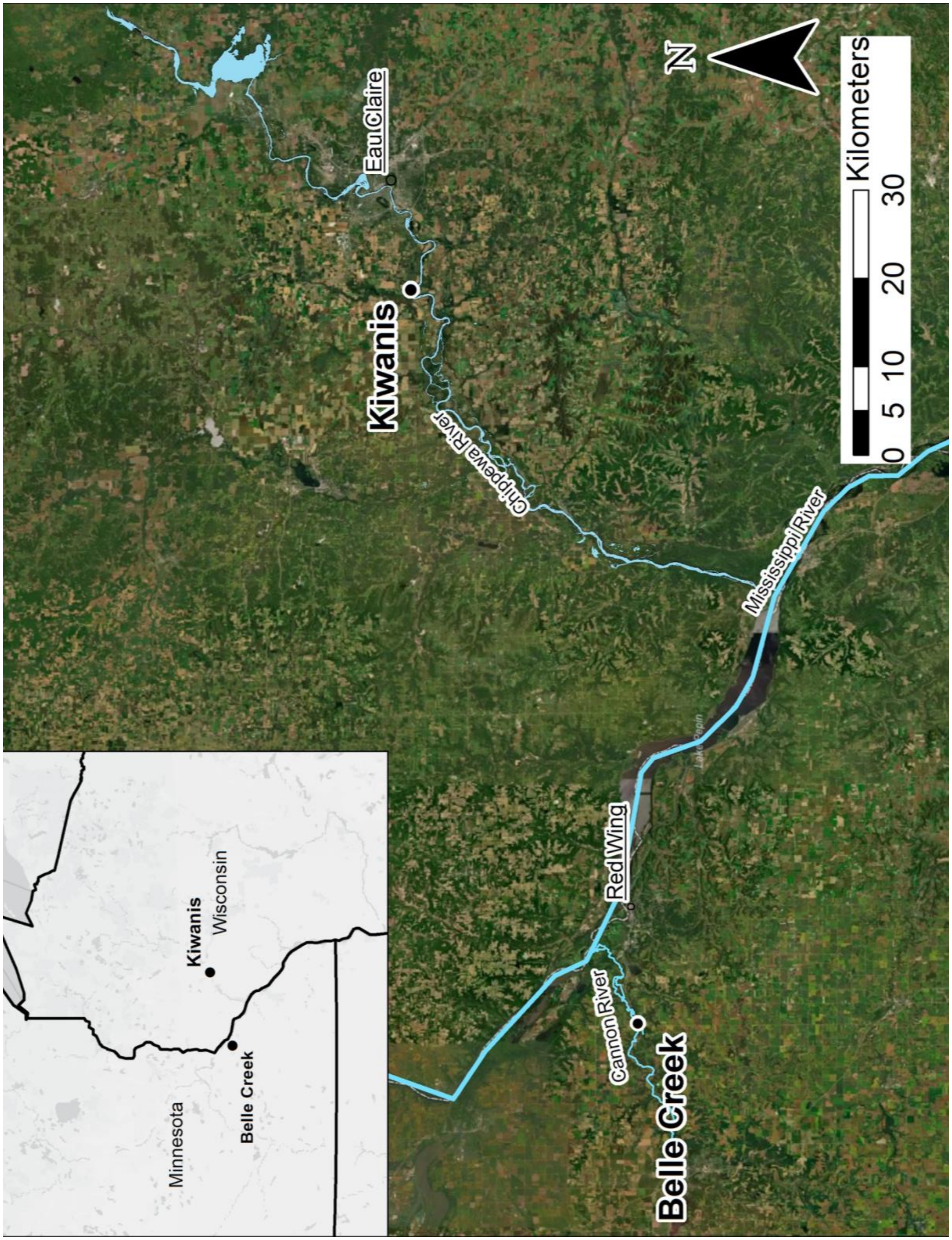

Figure 5: Location of the Belle Creek site in Minnesota in relation to the Kiwanis site. The Belle Creek site is a known cultural site with nearly 70 mounds. The same geophysical techniques applied to the Kiwanis site were applied to a mound at the Belle Creek site to see if comparisons could be made between the two sites.

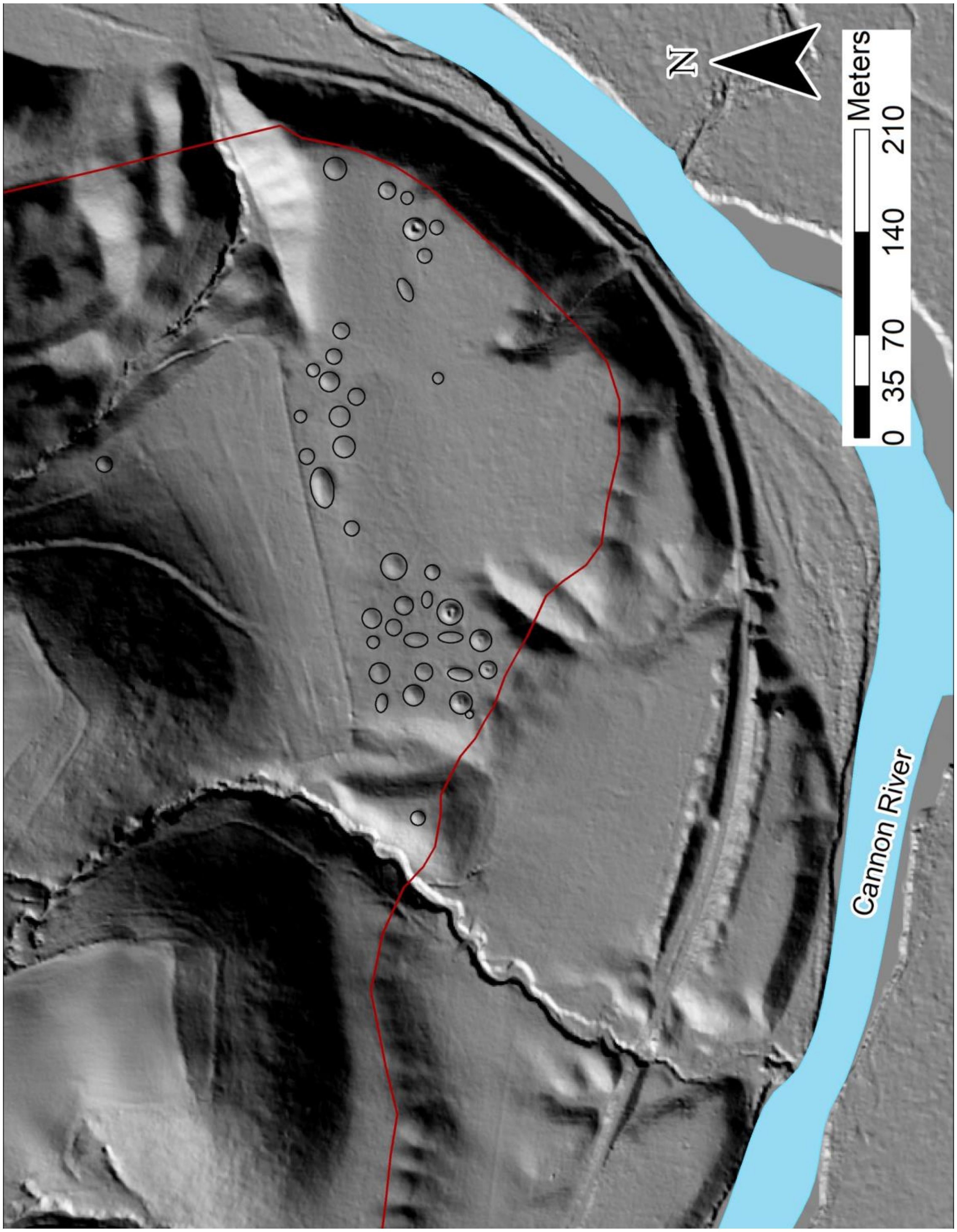

Figure 6: LiDAR imagery of the Belle Creek site with mound features, circled in black, visible atop a terrace (in red) along the Cannon River. The combination of linear and hemispherical features indicates the mounds did not form naturally. Further, depressions in the centers of some of the hemispherical mounds are the remnants of looter pits, within which artifacts were found.

2.0 Methods

Inspection of the Kiwanis site began in the Spring of 2018 with ground truthing of features following examinations of LiDAR imagery of the site (Figure 7). This was conducted in conjunction with members of descendant communities for their input as well as their consent to further investigate the mounds if it was deemed necessary. The investigations indicated that the features were similar to those documented as earthen mounds constructed by Late Woodland peoples throughout Wisconsin, Minnesota, Iowa, and Illinois (Birmingham and Eisenberg, 2000; Arzigian and Stevenson, 2003; Birmingham and Goldstein, 2005; Fagan, 2005). The confusion as to the origins of the features at the site along with their similar morphology to the prehistoric mortuary features prompted the need for noninvasive geophysical investigations. To assure adequate referential data, the results of the investigations would be compared to results from known anthropogenic mound features at another site, known as the Belle Creek site, due to the sparse existence of comparative geophysical data collected over mound features.

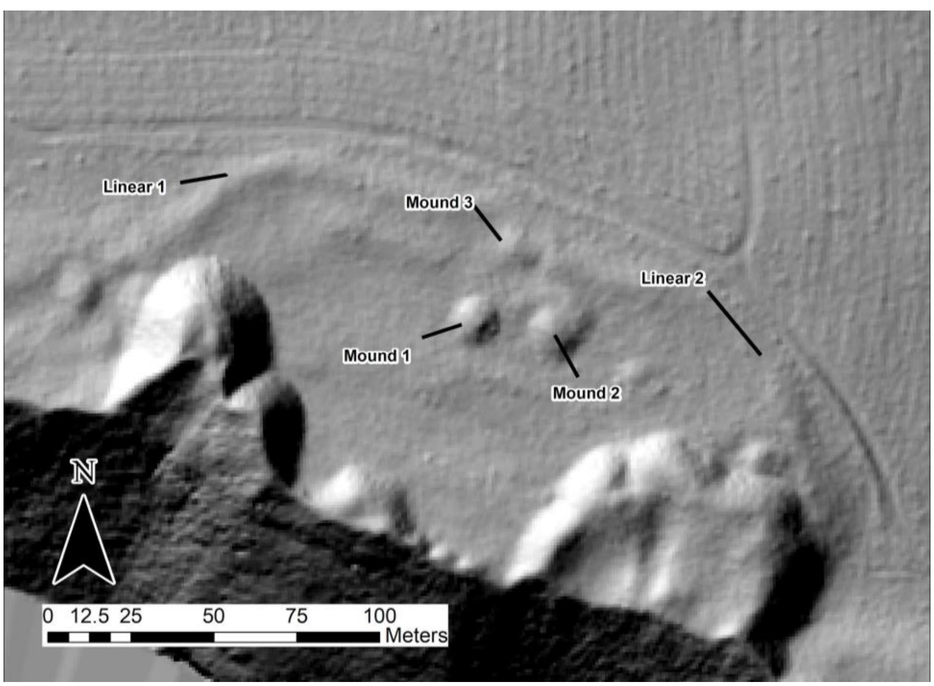

Figure 7: LiDAR image of the Kiwanis site with each of the mound features labeled and are the focus of this study. Mound 1 became the primary feature to be examined.

Previous studies at the Kiwanis site indicated that sediments at the site were 97% sand, specifically, medium, well sorted sand (Millett 2018). A multimethod geophysical approach consisting of GPR, magnetometry, and electrical resistivity was thus employed to noninvasively investigate the internal structure of the mound features. GPR was chosen due to the high electrical resistivity of the sandy sediments (Bristow and Jol 2003). The results can not only aid in the detection and visualization of sediment boundaries in radar data, but also deeper penetration of radar energy that would otherwise be absorbed by more conductive environments (Jol and Bristow 2003). Further, these data can be represented in pseudo-3D, allowing for an advanced spatial representation of subsurface anomalies for enhanced interpretation. Electrical resistivity was also chosen due to its regular use in archeological investigations and ability to detect changes in soil and sediment properties such as grain size, organic content, and level of saturation (Loke, 2004). Magnetometry, too, is regularly used in archeological investigations (Kvamme 2006, Hodgetts et al 2011), and thus was utilized in this study. Magnetometry is reliable in its ability to sense changes in induced or remnant magnetism brought about by human activity such as highly ferrous sediment layers caused by burning, or the removal, mixing, or piling of sediments (Smekalova et al. 2008). This multi-method approach utilizing GPR, electrical resistivity, and magnetometry ensures comprehensive analysis and accurate interpretation of cultural phenomena in data and is thus often chosen in archeological investigations (Nobes 1999, Dobbs et al. 2003, Clark and Clark 2003, Kaufmann 2005, Matais et al. 2006, Juerges et al. 2010, Johnson 2015, Nero 2016, Beck et al. 2018, Burds et al. 2018).

2.1 The Kiwanis Site

Surveys at the Kiwanis site included a total of 5 transects and one 20m x 20m grid surrounding the most prominent of the mound features at the site. Survey set up consisted of clearing of underbrush and establishing transect and grid survey locations. Brush and small vegetation that would otherwise inhibit accurate data collection were removed using hand tools while large trees greater than 4 inches in diameter were left in place to limit the impact on the environment caused by the surveys. Transects at the site were plotted to run roughly north to south and west to east over each of the hemispherical features. Start, end, and corner points for transects and the grid were recorded with GPS equipment to be plotted in ArcGIS following data collection. Data collection focused first on transect data and were collected with GPR. This was followed by surveys within the grid which were conducted using electrical resistivity and magnetometer, followed by GPR (Figure 8).

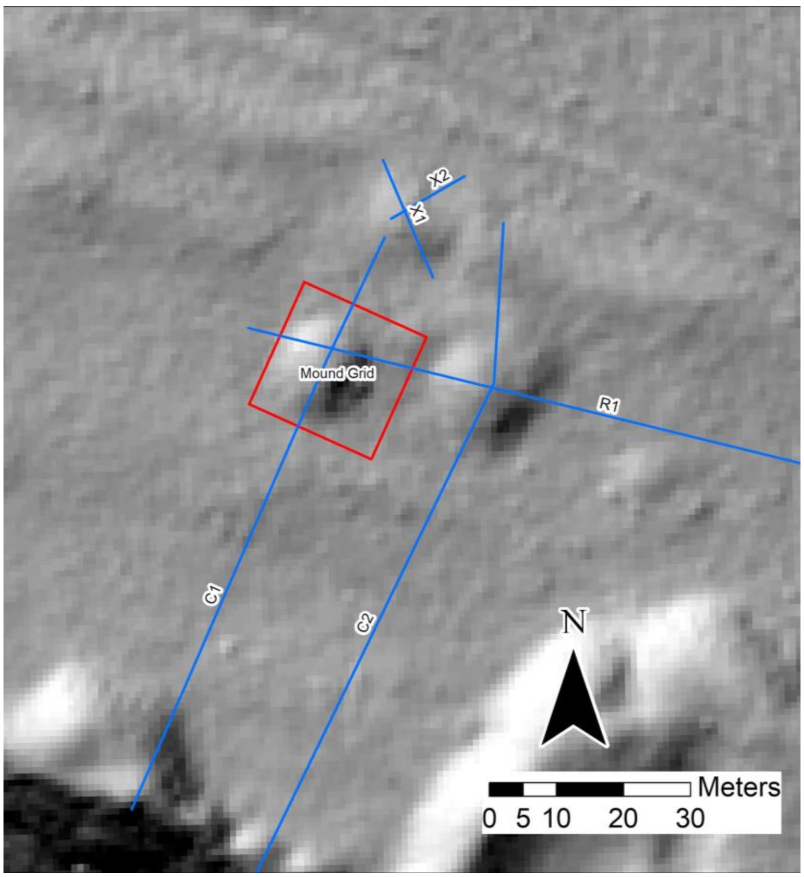

Figure 8: Map of geophysics grid (red) and GPR transects (blue) from the Kiwanis site. Electrical Resistivity, Magnetometry, and GPR grid surveys were conducted within the grid while GPR transects were collected along the blue lines to get a sense of what the stratigraphy around the mound looked like.

2.1.1 Kiwanis GPR Transects

A total of 5 transects were plotted running across each of the hemispherical mound features. Two of these transects ran from North to South, crossing over the southernmost hemispherical mound features and running up the leeward side of the parabolic dunes at the site. The western transect of the pair was labeled C1 with the eastern of the two being labeled C2. C1 measured 85m in length while C2 measured 98m in length. Another transect, labeled R1 running from West to East was also cleared and plotted, measuring a length of 102.1m. A pair of perpendicular transects crossing over the north-central mound were also plotted. These lines were labeled X1 and X2, X1 running North to South for 13.7m, and X2 running West to East for 17m. GPR data along these transects were collected using a Pulse EKKO 1000 GPR system with 500MHz and 200MHz antennae. Antennae were configured using the SmartTow setup in the broadside perpendicular orientation with a respective antennae spacing of 0.23m and 0.5. The respective step size used in the surveys was 0.02m and 0.1m. A time window of 40ns and 100ns along with a stack count of 64 and a velocity calibration set to 0.100m/ns were used, allowing for high resolution scans to a respective depth of roughly 2.2m and 2.5m.

Line	Length	Frequency	Velocity	Time Window	Depth of Penetration	Step Size	Stacks
R1	114m	200MHz and 500MHz	0.120m/ns	75ns	2.2m to 2.5m	0.1m and 0.02m	64
C1	94m	200MHz and 500MHz	0.120m/ns	75ns	2.2m to 2.5m	0.1m and 0.02m	64
C2	110m	200MHz and 500MHz	0.120m/ns	75ns	2.2m to 2.5m	0.1m and 0.02m	64

X1	15m	200MHz and 500MHz	0.120m/ns	75ns	2.2m to 2.5m	0.1m and 0.02m	64
X2	19.5m	200MHz and 500MHz	0.120m/ns	75ns	2.2m to 2.5m	0.1m and 0.02m	64

Table 1: Lines and line settings used on each of the lines collected at the Kiwanis site. A velocity of 0.120 was selected given the presence of sand at the site. A time window of 75ns was used on all lines, allowing for a depth of penetration of roughly 2m.

2.1.2 Kiwanis Electrical Resistivity

Geophysical survey within the 20m x 20m grid surrounding the mound at the Kiwanis site began with electrical resistivity. The electrical resistivity system used was a Geoscan Research RM15 resistance meter equipped with 4 local probes and 2 remote probes placed 20m away. The spacing between the local probes was 0.5m and 1m allowing for a respective depth of penetration of roughly 2.5m. The spacing between the remote electrodes was roughly 1m. Remote electrodes in this setup collect the ambient voltage and amperage of surrounding sediments. These readings are compared to induced electrical readings sent by the local probes. Remote probes are placed 20m away to avoid any interference from the induced current as the two readings are compared to one another to provide an understanding of the ease at which electricity can pass through the subsurface at the point of the induced current.

Data were collected along transects parallel to the Y axis of the grid. The first of these transects was placed at 0.5m along the X axis to ensure the current between each set of local electrodes arced directly over Line 0. Each subsequent transect was spaced two meters apart. This allowed for the collection of lines in an alternating direction and ensured that readings were taken along each meter within the grid. The step size along each of the transects was 0.25m, resulting in a total of 3,200 individual readings within the grid. An amperage of 1mA was used for each reading.

2.1.3 Kiwanis Magnetometry

Magnetometry data were collected within the same grid as electrical resistivity data to ensure comparisons between data would be accurate. The system used was the Geometrics G-858 magnetometer in the gradiometer mode. Sensor separation was 0.7m and data were collected every 0.1 seconds. Data were collected along transects spaced out every meter along the X axis. Data were also collected in a unidirectional fashion oriented towards the north. Data were stored in a grid format on the Geometrics G-858 control screen.

2.1.4 Kiwanis GPR Grid

GPR data collection was conducted within the same grid as electrical resistivity and magnetometry data using a Sensors and Software PulseEKKO_1000 GPR system with 500MHz antennae in both the X and Y directions. Resolution of the grid was increased to 0.5m line spacing to better hone in on the dimensions of subsurface anomalies. Antennae were configured in the SmartTow setup in the broadside perpendicular orientation with an antennae spacing of 0.23m. Step size used in the survey was 0.05m with a time window of 100ns. Stack count was set to DynaQ and a velocity calibration set to 0.100m/ns were used, allowing for high resolution scans to a respective depth of roughly 4.5m.

2.2 The Belle Creek Site

The Belle Creek site in Red Wing, Minnesota comprises a total area of 10 hectares. A rectangular area measuring 100m x 40m was plotted in the ArcMap GIS software and used in a concurrent study of the area as a whole in order to efficiently and effectively survey the site within one season. The location of the survey area was chosen in order to incorporate areas that were cultivated, not cultivated, and included mounds as well as areas between mounds and outside of the boundary of the mound group. In order to ensure the grid points plotted in ArcMap were plotted accurately in the field, a Trimble Total Station was utilized so that each grid point could be accurately shot to sub-centimeter accuracy.

This survey area was designed so that it could be split into 10 individual 20x20 grids that could each be individually surveyed by all three methods effectively. The 20m x 20m grid utilized in the comparison with Kiwanis data was a subset between grids 3 and 5 within this survey area and encompassed a large hemispherical mound. In addition to the secondary grid established around the hemispherical mound at the Belle Creek site, a total of 5 transects were also plotted that ran the length and width of the 100m x 40m survey area and bisected mound features therein (Figure 9). This, too, was done to generate a better understanding of the stratigraphy of the landscape surrounding the mound features at the site for comparison to the Kiwanis site.

2.2.1 Belle Creek Electrical Resistivity

Data were collected along North-South transects in an alternating fashion within grids 3 and 5 of the survey area. Transects were spaced out every 2 meters and a step size of 0.25m was used along each transect. The first line was placed at grid location 0.5, 0 to ensure readings were collected along the Y access and subsequent meter marks within the grid boundaries. This resulted in a total of 20 transects being collected and a total of 1722 individual readings per grid. Data between grids were normalized and clipped within the boundaries of the grid established around the hemispherical mound.

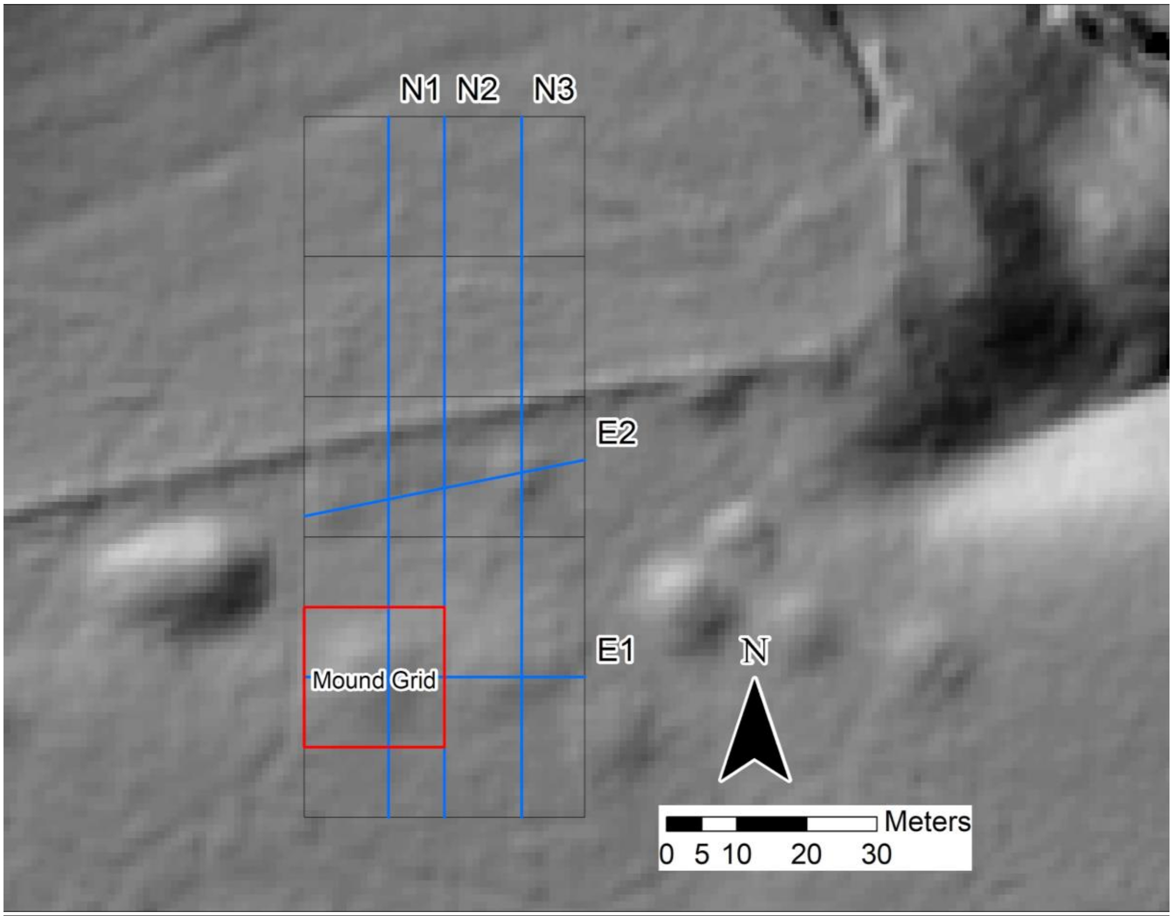

Figure 9: Map of the geophysics grid (red) and GPR transects (blue) collected at Belle Creek. Electrical Resistivity, Magnetometry, and GPR grid data were collected within the grid while GPR transects were collected along the blue lines, as was done at the Kiwanis site.

2.2.2 Belle Creek Magnetometry

Magnetometry data were collected following electrical resistivity data. The system used was the Geometrics G-858 magnetometer in the gradiometer mode. Sensor separation was 0.7m and data were collected every 0.1 seconds. Magnetometry data were collected over the same 20m x 20m grids and again normalized and clipped within the boundaries of the grid surrounding the hemispherical mound. Data were collected along transects spaced out every meter along the X axis. Data were also collected in a unidirectional fashion oriented with Magnetic North.

Data were stored in a grid format on the Geometrics G-858 control screen.

2.2.3 Belle Creek GPR Transects

GPR data collection at Belle Creek began with the 5 transects established within the 100m x 40m survey area. Three transects ran North to South for 100 meters followed by 2 running West to East for 40 meters. Each transect was collected using 100 MHz, 200 MHz, and 500 MHz antennae.

North-South transects were named N1, N2, and N3, with N1 starting at grid location 12, 100, N2 at grid location 20, 100 and N3 at grid location 31, 100 (Figure 9). Transect locations were chosen so N1 would parallel with the Y axis and cross over the western, large sand mound within the southern half of the survey area. N2 was fit to the center of the grid as it was unobstructed by trees and ran between the western and eastern sand mounds within the southern half of the survey area. N3 was laid out so it would cross over the eastern sand mound. The locations of N1 and N3 were chosen as well to minimize obstructions along their paths.

West to East transects were named E1 and E2 due to their generally Eastward orientation with E1 located at 0,20 along the boundary between grids 1 and 2, and 3 and 4, and E2 located at 0,43 to 40, 51. The orientation of E2 was angled due to obstructions by trees and to ensure the transect ran over mounds that fell within grids 5 and 6 (Figure 9).

Transects data were collected using 100MHz antennae utilized a time window of 200ns, velocity of 0.06m/ns, and a step size of 0.25. A lower velocity for the survey was selected based on the presence of fine grained sediments in the north part of the survey area, visible in soil probes collected there. Stacks were set to the DynaQ mode to auto adjust to the speed of operator movement and ensure GPR traces would not be missed. Transects collected using 200MHz antennae utilized a time window of 200ns, velocity of 0.06m/ns, and a step size of 0.1m. Stack count was again set to DynaQ to ensure traces were not missed. Transects collected using

500MHz antennae utilized a time window of 150ns, velocity of 0.06m/ns, and a step size of 0.05m.

Line	Length	Frequency	Velocity	Time Window	Depth of Penetration	Step Size	Stacks
N1	100m	100MHz, 200MHz, and 500MHz	0.06m/ns	200ns, 200ns, and 100ns	2m	0.25m, 0.1m, and 0.02m	DynaQ
N2	100m	100MHz, 200MHz, and 500MHz	0.06m/ns	200ns, 200ns, and 100ns	2m	0.25m, 0.1m, and 0.02m	DynaQ
N3	100m	100MHz, 200MHz, and 500MHz	0.06m/ns	200ns, 200ns, and 100ns	2m	0.25m, 0.1m, and 0.02m	DynaQ
E1	40m	100MHz, 200MHz, and 500MHz	0.06m/ns	200ns, 200ns, and 100ns	2m	0.25m, 0.1m, and 0.02m	DynaQ
E2	43.5m	100MHz, 200MHz, and 500MHz	0.06m/ns	200ns, 200ns, and 100ns	2m	0.25m, 0.1m, and 0.02m	DynaQ

Table 2: Lines and line settings used on each of the lines collected at the Belle Creek site. A velocity of 0.06 was initially selected due to the presence of fine, wet particles near the start of the lines. However, this was corrected to 0.110m/ns using hyperbola calibration. A time window of 100ns was used on all lines, allowing for a depth of penetration of roughly 3m.

2.2.4 Belle Creek GPR Grid

GPR grid data at the Belle Creek site was solely focused within the grid established between grids 3 and 5. Data collected at this site were collected in an alternating fashion in both the X and Y direction. Line spacing was 0.5m in order to conserve time without a loss in resolution. 500MHz antennas were also utilized in order to gain high resolution data for visualizing changes in sediment boundaries as well as locating areas that could be culturally significant. A time window of 150ns was used as well as a velocity of 0.06m/ns. A step size of 0.05m was also used as well as the use of the Dyna Q to ensure efficient and accurate data collection was conducted.

2.3 Electrical Resistivity Data Processing

Each individual reading was saved on the Geoscan Research RM15 resistance meter. Data were exported from the machine and then converted into a Microsoft Excel document including the relative X and Y location of each point within the grid as well as the associated reading in Ohms. These data were then brought into the Surfer version 19.1.189 mapping software that interpolates and displays data with an X and Y component. Displayed data were fit along a normal curve to better visualize differences in electrical conductivity within the subsurface.

Due to an issue with the internal storage capabilities of the resistivity machine, each of the readings had to be collected by hand which substantially increased the time it took to collect resistivity data. However, it allowed for quick input of the data into an excel document that could not only be brought into Surfer, but also directly into ArcMap.

Because data were collected within different grids and within different sediments, data needed to be normalized in order to accurately examine differences in resistivity within the entirety of the grid. Changes in soil sediments can lead to radically different resistance values over large areas and thus the amperage of electrical pulses sent into the subsurface needed to be increased or decreased. Further, the length of the wires connected to the remote electrodes required that they be moved prior to each survey. Normalization makes data appear as if they were collected continuously as opposed to at different times, in different locations, or with different settings. Thus, data were normalized to readings taken at grid 1 in the southwest corner of the survey area.

The process of normalization, developed in the field, involved taking readings taken from the same location within both grids, finding the difference between the two readings, and applying that difference to all other readings collected in a grid that needed to be normalized. This process was possible as grids shared either a final X or Y line with an initial X or Y line in a subsequent grid. For example, Y line 20 within grid 1 was the same line as Y line 0 within grid 2, meaning readings could be adjusted based on the difference between readings when data collection on these grids was conducted.

Following data collection, data were entered into a Microsoft Excel spreadsheet and exported into the Surfer mapping software. This software was able to plot data in an X and Y format with their associated readings from either 0.5m or 1m spaced electrodes and display them in a depth slice format.

2.4 Magnetometry Data Processing

These data were exported into the MagMap 2000 version 4.96 software that both processes and exports the data files saved by the system into a Microsoft Excel file, but also allows for initial interpretation of magnetometer results. Data exported from this software included the relative X and Y location of each reading from both the top and bottom sensors, as well as the vertical gradient of the two sensors, the top sensor subtracted from the bottom sensor. Data were then brought into the Surfer mapping software to further aid in visualization. Data were constrained along a normal curve.

2.5 GPR Data Processing

The Sensors and Software PulseEKKO 1000 GPR system automatically generates a .GPZ project file when data are exported from the device, making data processing easier. When data are brought into EKKO_Project, a variety of options can be applied to the data to aid in enhanced visualization and interpretation. For data from the Kiwanis and Belle Creek sites, Hyperbolic Velocity Calibration and Topographic adjustments were applied along with the Dewow, Highpass, SEC2 Gain, and Data Migration filters were applied to each transect and grid datasets.

2.5.1 Hyperbolic Velocity Calibration

Velocity calibrations in the field are based on the expected velocity a wave will travel through a medium based on a basic understanding of the sediment the survey is being conducted upon. However, these calibrations are not an accurate reflection of the speed at which a radar wave is traveling due to changes in things such as soil moisture, sediment size, etc., along the transect or at depth. The depth at which readings are displayed will be inaccurate because of this as they are calculated by the equation $D=v*t/2$. Thus, in order to make accurate interpretations of subsurface features and stratigraphy, velocity needs to be recalculated along each transect. This is done using the Hyperbola Velocity calibration tool within EKKO_Project. This tool allows the user to fit a hyperbola to hyperbolic reflections within the data whose width more accurately affects the speed at which a wave is moving through a medium. This process was done on 5 visible hyperbolas along each of the 8 transects to correct depth calculations.

2.5.2 Dewow Filter

Induced radar frequencies are not the only frequencies picked up by the GPR receiver. Included in the data are low frequency, slowly decaying energy that can be a result of the electrical conductivity of a medium GPR data are collected in (Sensors and Software, 2005). Thus, this filter is applied to remove the low frequency readings and keep high frequency readings that are the focus of data analysis. This filter is automatically applied to all data in post processing.

2.5.3 SEC2 Gain filter

This filter is a method of visualization known as Spreading & Exponential Calibrated Compensation. According to Sensors and Software (2005), “Applying this process with suitable parameters makes the amplitudes of signals returned from similar targets at different depths appear similar.” In other words, the amplitude of a return wave from depth is displayed in relation to its surroundings rather than the actual amplitude of the return. This makes subsurface strata and objects appear as though their amplitudes are similar on return regardless of depth.

2.5.4 Topographic Adjustments

Initial GPR data are plotted without taking changes in topography into account. The precise depth as well as the orientation of stratigraphy is therefore geometrically incorrect without topographic adjustments being applied. In order to accurately collect these data, a TopCon laser leveling system was used. Measurements were collected at every meter along each of the transects and entered into a Microsoft Excel spreadsheet. In instances where the laser was obstructed due to trees, the TopCon system was moved and a second reading was taken from the final previous reading. These data were then normalized in Excel.

These normalized readings were not an accurate reflection of the changes in topography, though. Instead, they mirrored the topographic changes along each transect, creating an incorrect adjustment if the readings were applied to each transect. In order to solve this, the lowest point in elevation along a transect in question, identifiable by the highest value within the spreadsheet, was identified. This value was then subtracted from each of the values in the spreadsheet, followed by multiplying all values by -1. This effectively made the lowest point along the transect 0 and made all following values positive to accurately reflect changes in topography along each transect.

In cases where topographic data were not collected, LiDAR data were substituted. These data were brought into ArcMap GIS software along with transect and grid data. Transect data were converted from lines to points spaced out every 1m along each transect using the Generate Points Along Line tool. Elevation data from digital elevation models generated using LiDAR data were then extracted at each of the points along each transect using the Extract Values to Points tool. The table created using this tool was then exported from ArcMap into Microsoft Excel and converted into a .top file that is used to add topographic data to transects in the EKKO_Project processing software. Topography data from GPR grids followed a similar process, however transects had to be created within grid boundaries. These transects were spaced 0.5m apart with points generated along each grid transect every 0.5m.

3.0 Results

Geophysical surveys at the Kiwanis site consist of GPR transects as well as a grid within which GPR, electrical resistivity, and magnetometry surveys were conducted upon the most prominent hemispherical feature at the site (Figure 10). Data gathered at the Belle Creek site were additionally collected as transects within and around the most prominent hemispherical feature within the study area, and within a 20m x 20m grid surrounding the mound (Figure 11). However, given the cultural nature of the site, transect data from grid data collected at the Belle Creek site was utilized for comparative analyses between it and the Kiwanis site.

Following data processing, analyses of results were conducted to locate anomalous areas in the data. Anomalies are areas that are characteristically different from their surroundings, such as an increase or decrease in the investigated phenomena. These areas can be better visualized using color ramps to show where within a survey space more substantial anomalies exist. However, anomalies do not prove the existence of artifactual information in surveys. Instead, they solely indicate that an area within the survey may be of interest for further investigation regarding its origins. Yet, anomalies that are unnatural in shape can be reasonably deemed to be cultural in origin without disturbance of the subsurface. In the case of the Kiwanis site, anomalies that suggest the mound is made of material different that what surrounds it, or contains anomalies within the mound are found to contain right angles or are composed of markedly different material from the mounds themselves, it is highly probable that such features are cultural.

3.1 GPR Transects

GPR transects at the Kiwanis site were collected North to South as well as West to East over mounds 1, 2, and 3 (Figure 10 in blue). The resulting images display black and white lines, known as reflections, that represent changes in the dielectric constant of subsurface materials. Each pair of black and white lines in the processed images indicates a contrast between two differing materials. By examining the orientation of the reflections as well as their strength, it is possible to interpret what likely caused their deposition as well as the boundaries of different features.

Figure 12 is a 20m transect from the center of the GPR grid at the Kiwanis site running from Northeast to Southwest over the mound. Black and white line pairs are boundaries between sediment layers of contrasting dielectric constant. Analysis of these images involves interpreting

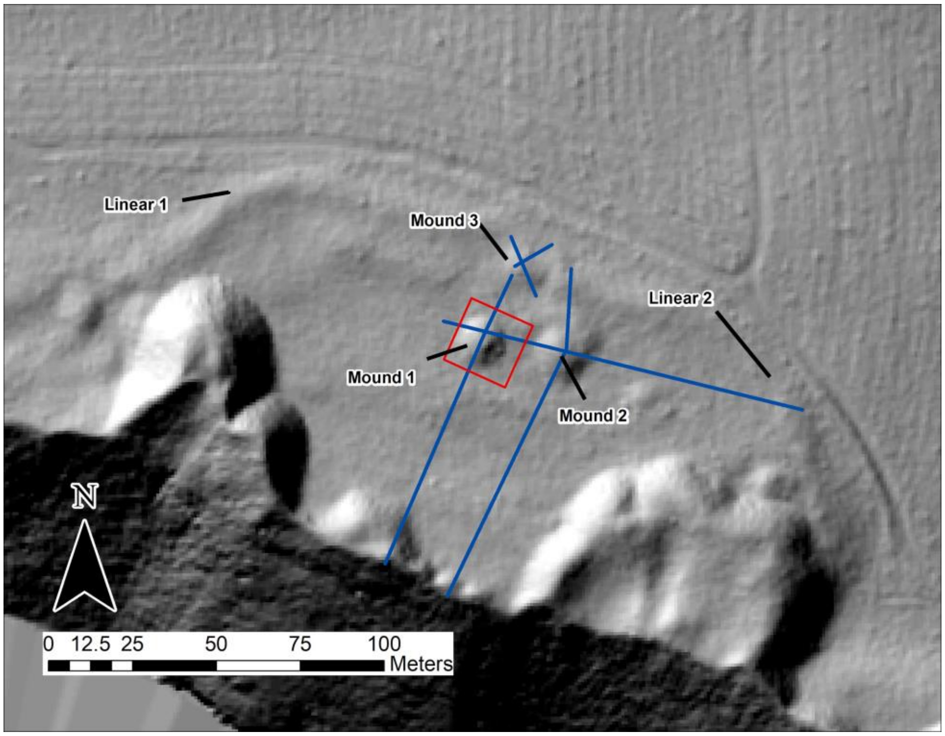

Figure 10: Map of data collected at the Kiwanis site with transects in blue and the geophysical grid in red.

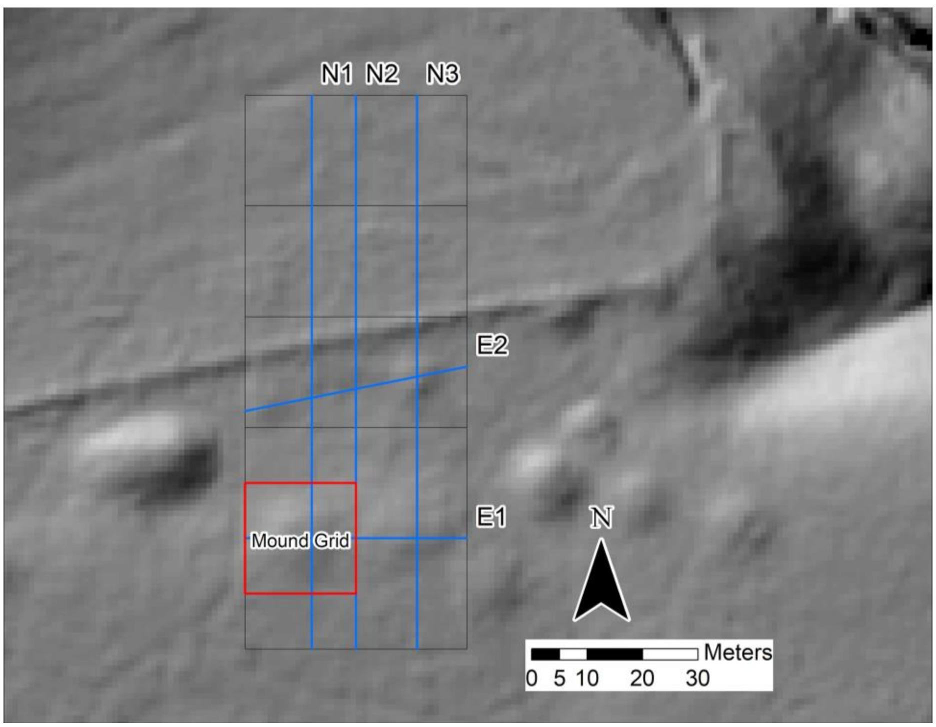

Figure 11: Map of data collected at the Belle Creek site with transects in blue and the geophysical grid in red.

the orientation of these boundaries. The orientation of the reflections are either semi continuous or hummocky and dip down and away from the mound apex.

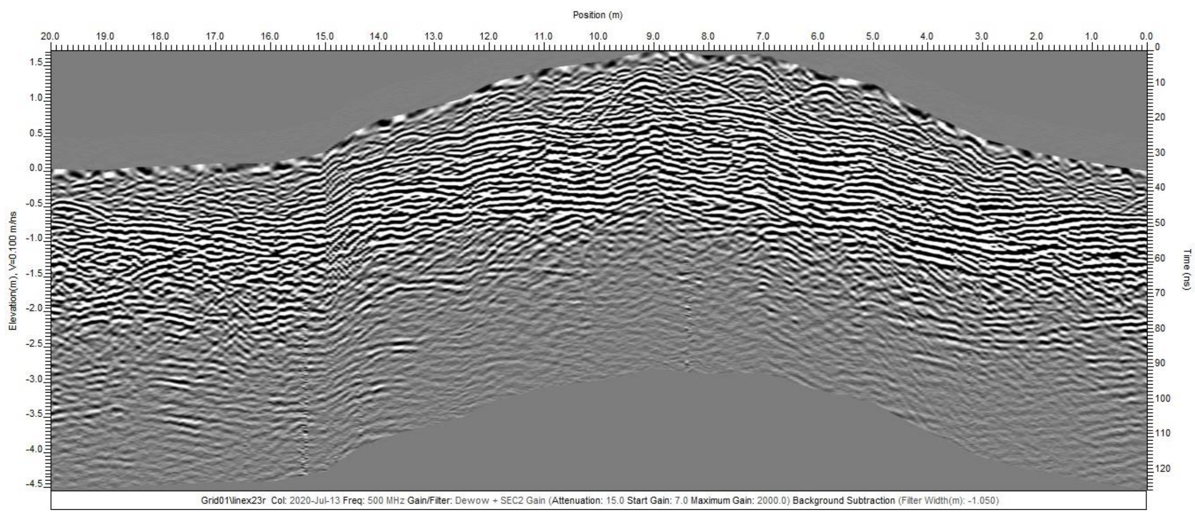

Figure 12: 500MHz GPR transect from the geophysics grid running from northeast to the southwest at the Kiwanis site. Stratigraphy within the mound is hummocky and dips away from the mound apex.

Figure 13 is also taken from the center of the geophysical grid surrounding the mound at the Kiwanis site from west to east. The internal orientation of the reflections again dip down and away from the mound apex. Due to the similar orientation of the reflections in both the X and Y directions, GPR data suggest that horizons dip away from the mound apex in all directions.

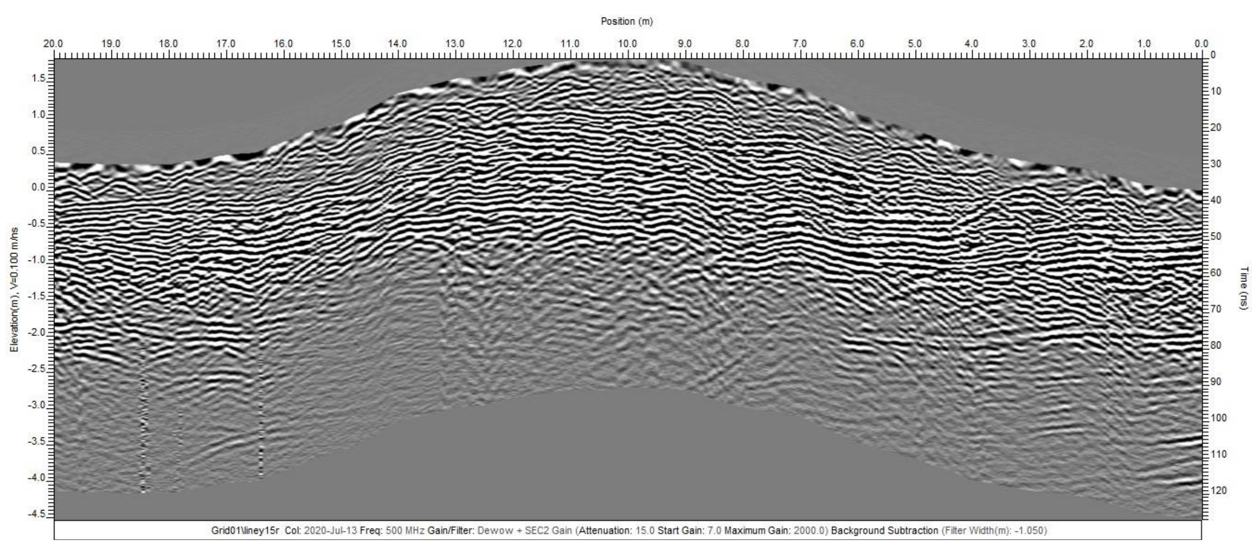

Figure 13: 500MHz GPR transect from geophysics grid running from northwest to the southeast, perpendicular to Figure 12. Reflections again indicate the stratigraphy within the mound is hummocky and dips away from the mound apex.

This contrasts with what is visible in the stratigraphy of aeolian features surrounding the Kiwanis site (Figure 14) that contain slipfaces between 57m to 69m and 75m to 84m that build upon one another over time from southwesterly wind regimes.

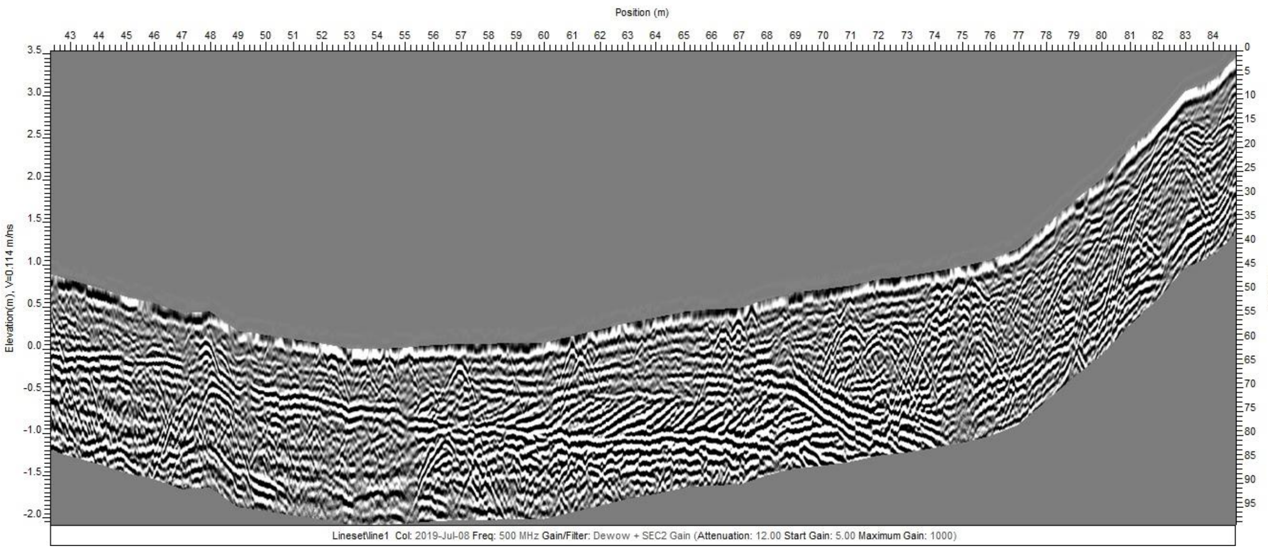

Figure 14: 500MHz GPR transect data from the Kiwanis site running up one of the dune features located nearby. Slipfaces can be seen between 57m to 69m and 75m to 84m. Similar reflections would be expected within the mound if it formed through aeolian processes.

When transect data from the Kiwanis site are compared with transect data from the Belle Creek site, similar patterns emerge. In figure 15, a transect from west to east within the grid surrounding the mound at the site, stratigraphy within the mound appears to dip away from the mound apex. This too is visible within transect data running from North to South within the grid surrounding the mound at the Belle Creek site in figure 16. Due to this, GPR transect data suggests that mound stratigraphy dips away from the mound apex in all directions.

3.2 GPR Depth Slices

Results in Figure 17 and 18 are from GPR grid data collected over the mound at the Kiwanis site following data processing using EKKO_Project processing software. This program

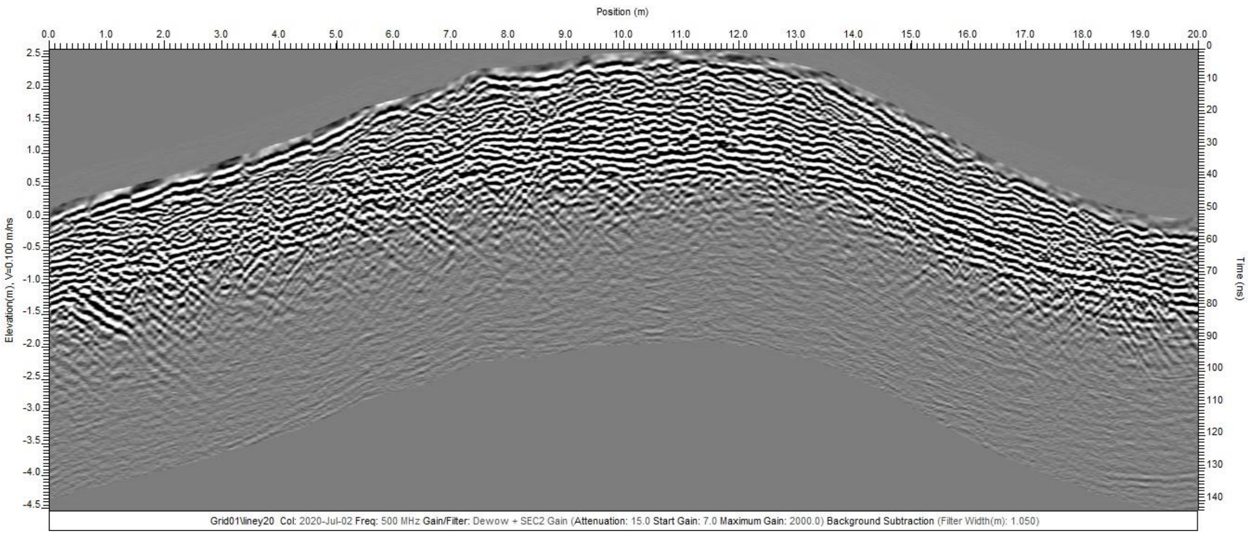

Figure 15: 500MHz GPR Transect running west to east over the center of the mound at the Belle Creek site. The reflections in this transect indicate the stratigraphy of the mound is hummocky and dips away from its apex, similar to what is seen in the Kiwanis mound..

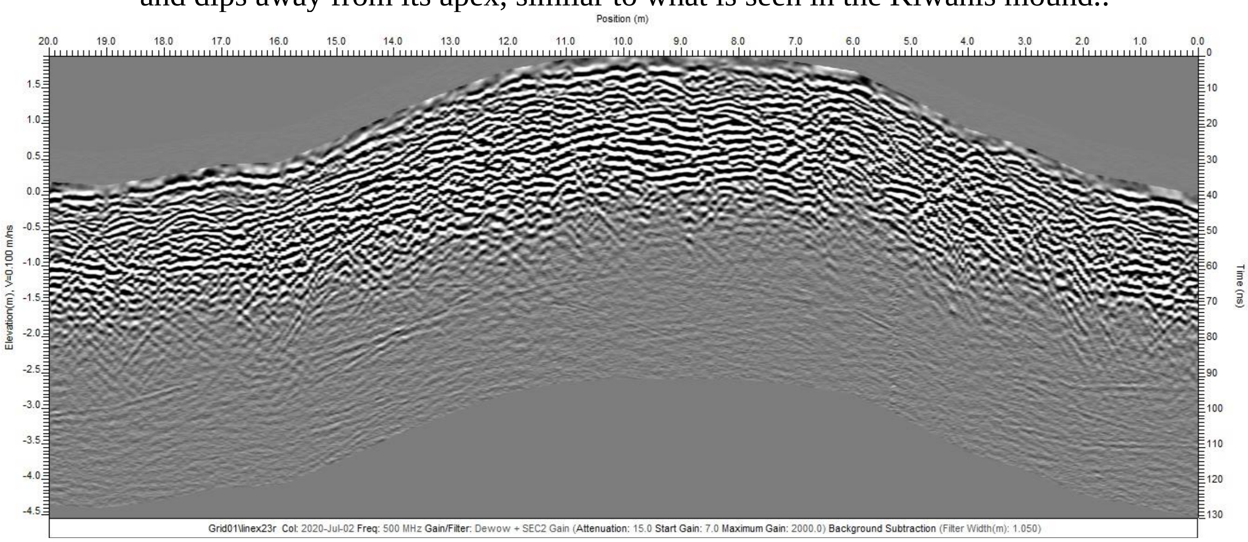

Figure 16: 500MHz GPR Transect running west to east over the center of the mound at the Belle Creek site. The reflections in this transect indicate the stratigraphy of the mound dips away from its apex as well, meaning mound fill dips away from its apex on all sides, similar to what is seen at the Kiwanis site.

allows for the interpolation of readings at the same depth within a grid, leading to the creation of depth slices and enabling visualization of the spatial extent of subsurface anomalies. Figure 17 is a depth slice from the Kiwanis site from 1.45m to 1.5m below the surface of the mound. Data results are displayed along a warm to cold color ramp and apply a color to pixels within the slice based on the intensity of the return observed there. Areas in red are areas where radar energy returns are much more intense, meaning the contrast between the dielectric constant of the red areas and their surroundings is much greater, resulting in an increase in returned energy. In contrast, areas in blue indicate a much weaker return of radar energy, due to the similar dielectric properties of overlain materials.

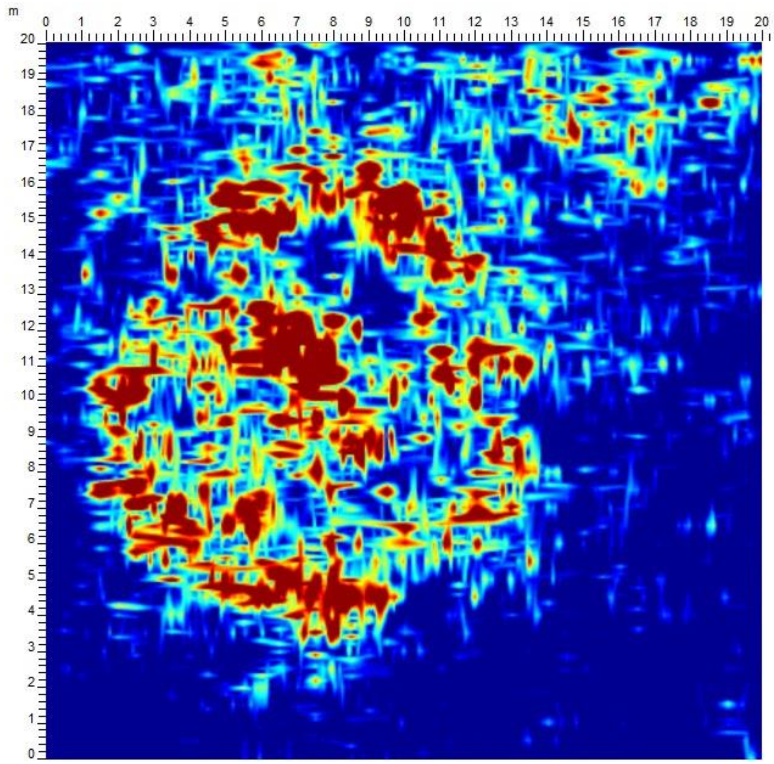

Figure 17: Depth slice from 500 MHz GPR grid data collected at the Kiwanis site at 1.5m below the surface. Red areas indicate where dielectric properties between these zones and their surroundings contrast greatly. These reflections are near the base of the mound and could indicate a prepared surface.

Initially visible in Figure 17 is a circular area of high reflection that falls within the boundaries of the mound. The intensity of this return indicates that the sediments making up the mound fill are different from their surroundings. This could be the result of materials from elsewhere being brought in while the mound was formed or due to mixing of materials during mound construction. Additionally, a semi rectangular anomaly is visible in this depth slice toward the center of the mound at roughly 1.5 meters below the surface, the orientation of which is north to south when mapped (Figure 18). The sharp right angles of this anomaly coupled with the high degree of contrast with the mound fill suggests an unnatural origin to this feature.

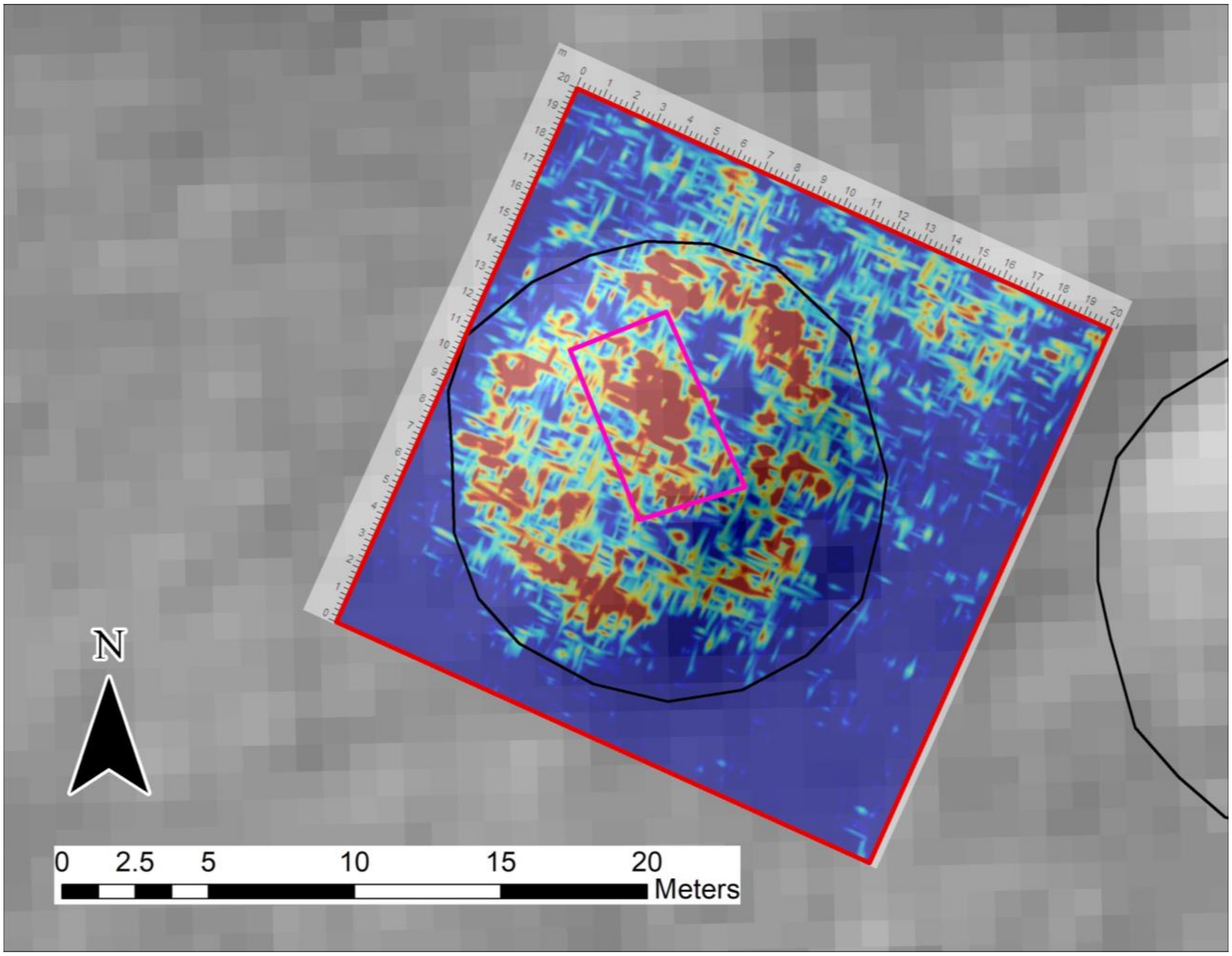

Figure 18: Depth slice 1.5 meters below the surface of the mound at the Kiwanis site. Grid boundaries are indicated in red, mound boundaries are indicated in black, and a rectangular anomaly is indicated in pink. This rectangle could be a burial feature within the mound given its size and orientation.

Figure 19 (below) is the results of GPR grid data from 0.75m below the surface of the mound at the Belle Creek site that suggest the mound fill differs from its surroundings, similar to what is seen at the Kiwanis site. Again, a color ramp is applied to the depth slices produced in processing where warm colors represent areas where the difference in dielectric constant differs greatly from that of its surroundings while cool colors indicate areas where the contrast is much weaker.

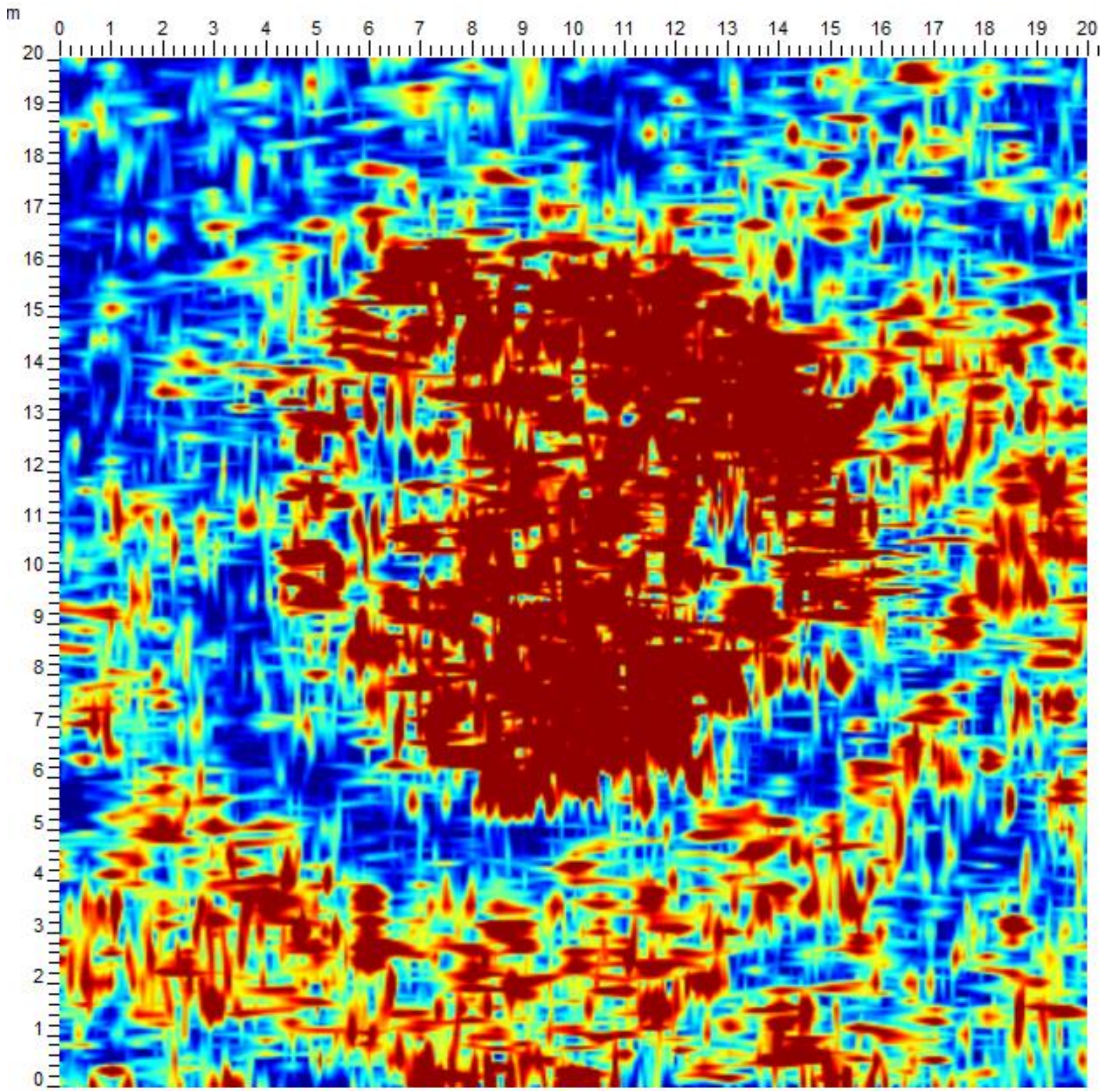

Figure 19: Depth slice from the Belle Creek mound at 0.75m below the surface. Red areas indicate where dielectric properties between these zones and their surroundings contrast greatly. Similar to what is seen at the Kiwanis site, the intensity of this reflection could be from a prepared surface at the base of the mound.

When this depth slice is mapped, results indicate that this area of high return is concentrated within the boundaries of the mound (Figure 20 in black). This suggests the fill within the mound is extensively different from its surroundings due to the intensity of the return therein. The low return areas at the left and right edges of the mound are caused by GPR transects being interrupted by large trees.

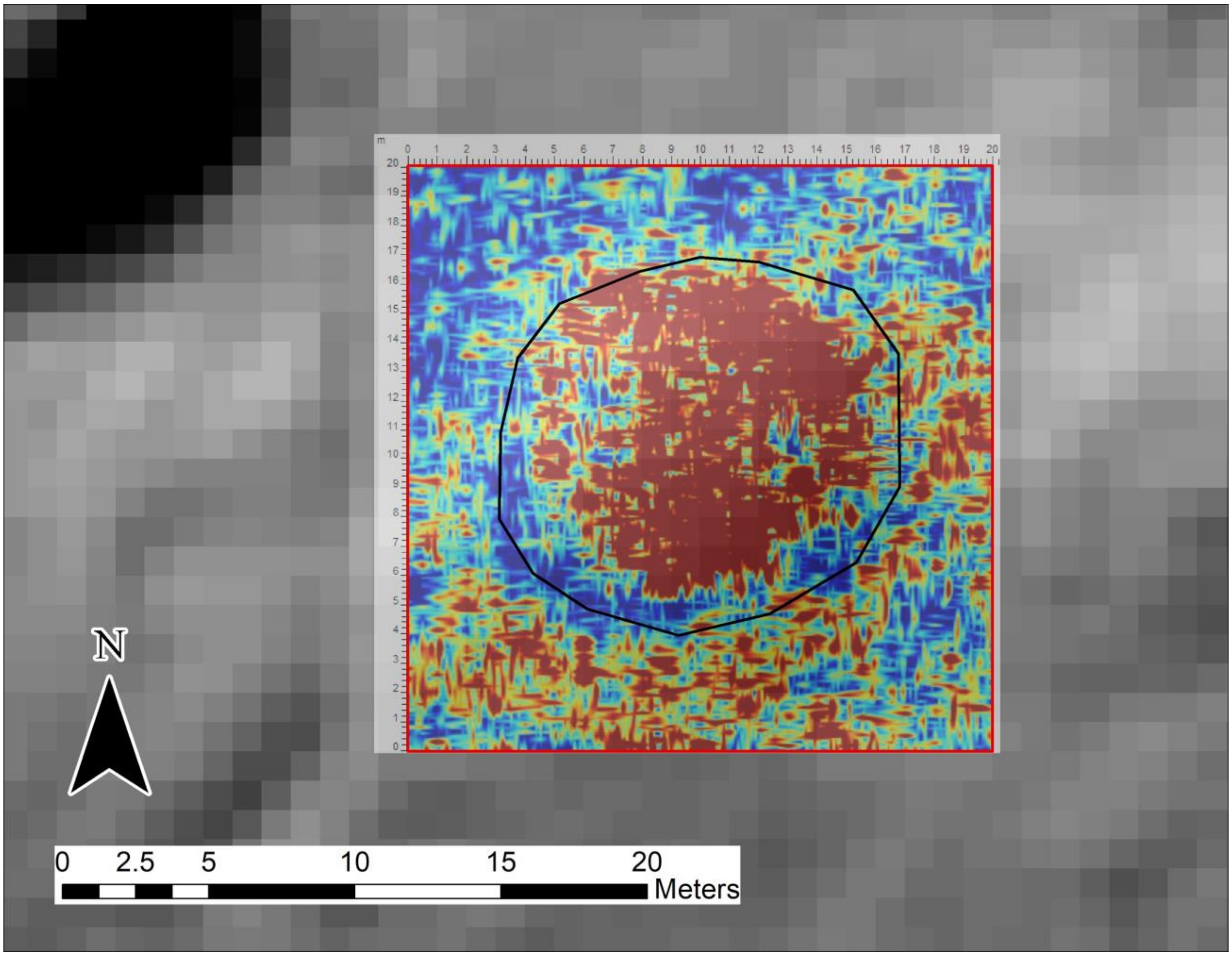

Figure 20: Depth slice at 0.75 meters below the surface of the mound at the Belle Creek site. Grid boundaries are indicated in red while mound boundaries are indicated in black, illustrating that the highly reflective surface falls fully within the mound.

The intensity of the returns as well as their central, circular origin within the mounds at both the Kiwanis and Belle Creek sites indicates that the material comprising the mound features at both sites differs greatly in dielectric constant from that of the material that surrounds them. Whether this material is a result of mixing of surficial and subsurface sediments during mound construction or the result of material being deposited within the mound from elsewhere is indeterminate, yet the anomalous nature of the mound fill suggests mound fill is characteristically different from the surrounding sediments. Further, the central, rectangular anomaly that is oriented towards the cardinal directions within the Kiwanis mound indicates a feature of probable cultural origin exists within.

3.3 Electrical Resistivity

Resistivity data processed using the Golden Software Surfer processing software allows for the interpolation and visualization of individual data points across a gridded space, similar to a depth slice produced in Ekko_Project software from GPR readings. A warm to cold color ramp was applied to the results, displaying areas with increased resistance to electrical currents in red while areas with decreased resistivity are indicated in blue. Figure 21 (below) illustrates electrical resistivity readings from roughly 0.5m below the surface.

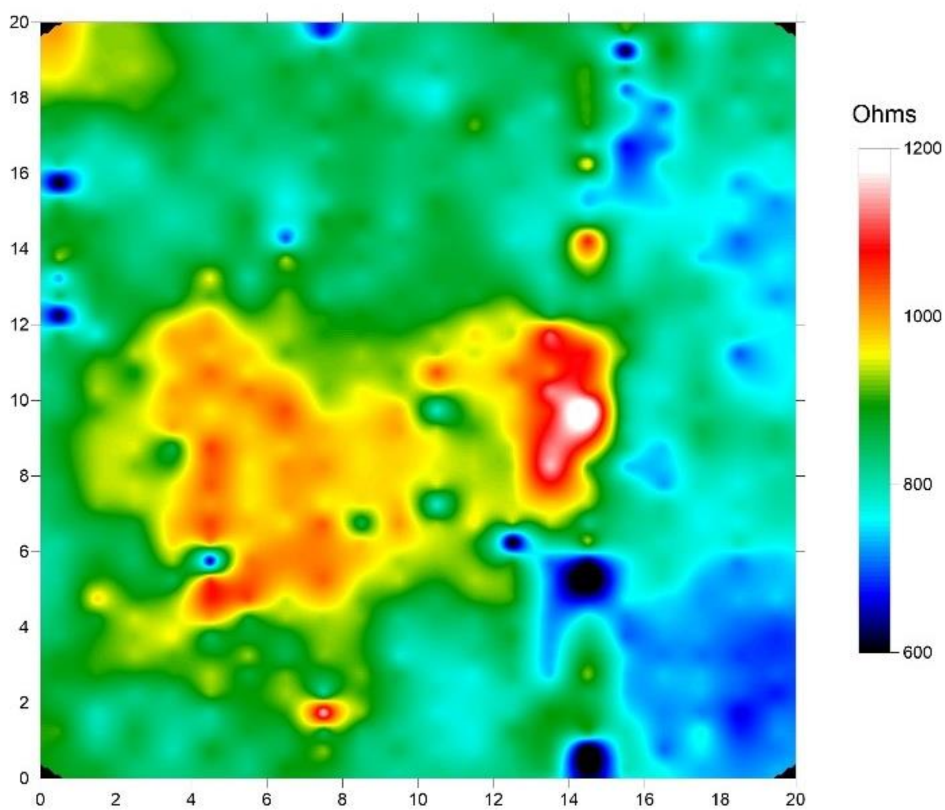

Figure 21: Results of electrical resistivity readings at the Kiwanis site from 0.5m below the surface. Warm colored areas are those where resistivity is higher while cooler areas indicate places where the subsurface is more conductive.

When these results are mapped (Figure 22), they indicate that resistive areas are concentrated towards the southern half of the Kiwanis mound and are concentrated towards the southwestern part of the mound. While this may be caused by a variety of factors (Loke 2004) it does indicate mound fill contains materials different from the surrounding material or the result of a disturbance of the mound, leading to the concentration of high electrical resistance.

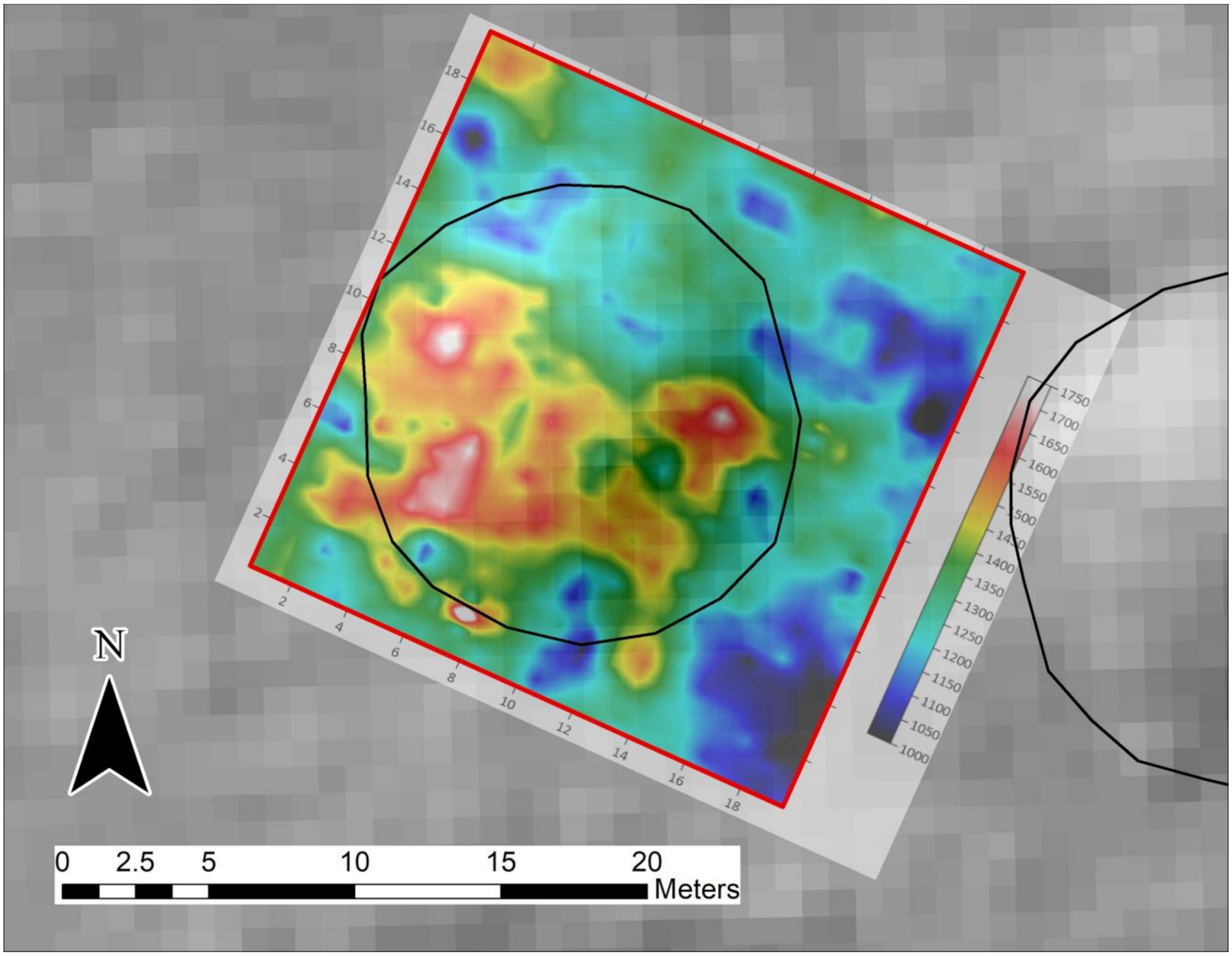

Figure 22: Mapped results at 0.5 meters below the surface of the mound at the Kiwanis site. Grid boundaries are indicated in red while mound boundaries are indicated in black. Resistivity anomalies are visible within the boundaries of the mound, indicating the mound may be made of material that is physically different from its surroundings.

Results of electrical resistivity grid data collected over the Belle Creek mound share similar characteristics. Figure 23 displays changes in electrical resistivity from about 0.5m below the surface with warm colored areas representing locations where less electricity passes through while cool colored areas represent locations where more electricity passes through more readily.

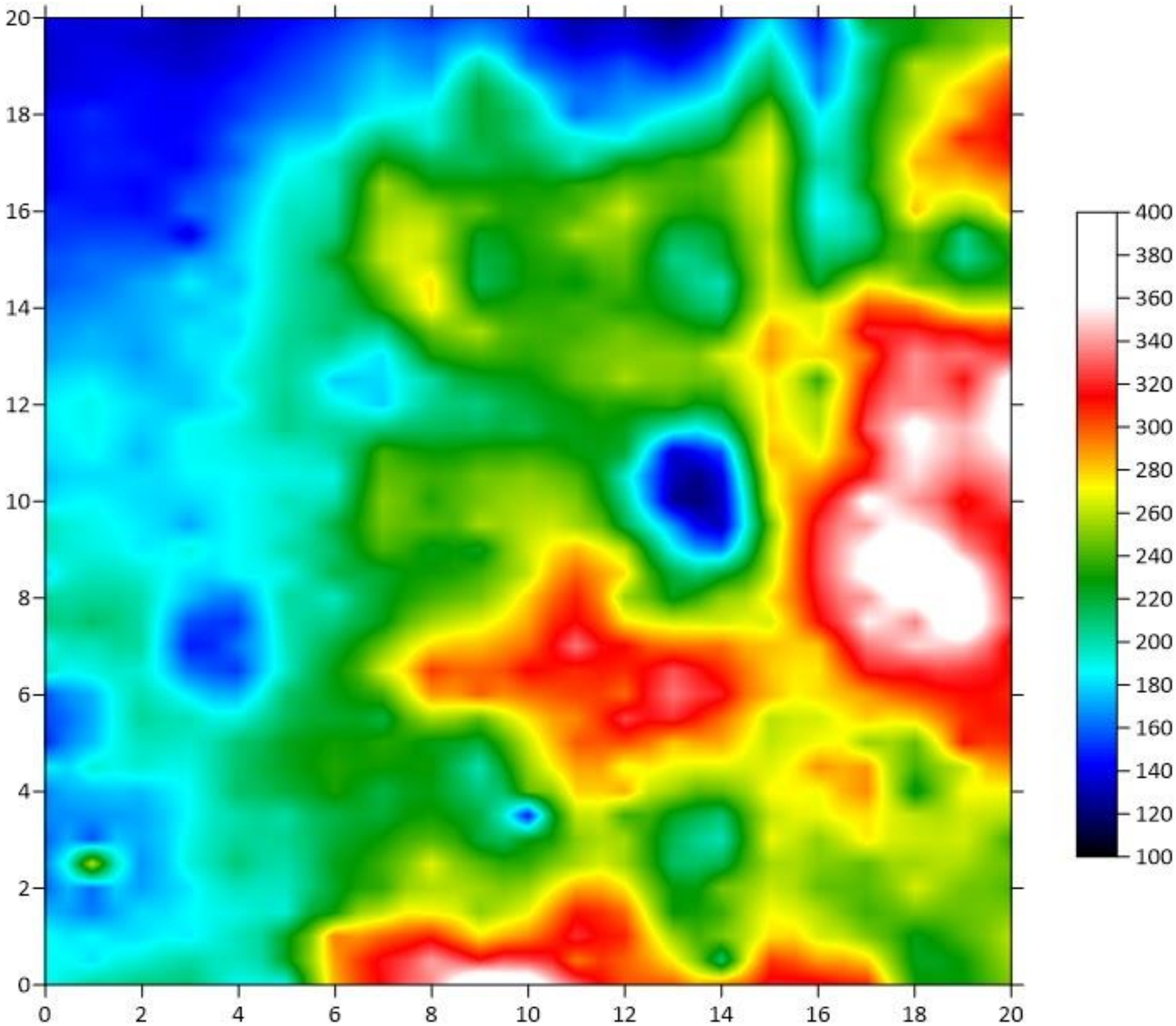

Figure 23: Results of electrical resistivity readings at the Belle Creek site from 0.5m below the surface. Warm colored areas are those where resistivity is higher while cooler areas indicate places where electricity has an easier time passing through the subsurface.

When these results are mapped, it can again be seen that highly resistive areas within the mound boundary (Figure 24 in black) tend to be located in the southern half of the mound, increasing in electrical conductivity moving north. Further, a slight increase exists throughout the mound itself while a decrease exists to the west and northwest of the mound. This is likely a result of the increase in silt sized particles north of the mound site, leading to an increase in conductivity due to increases in saturation. These results suggest that mound fill may be composed of different material than its surroundings, similar to what is seen at the Kiwanis site.

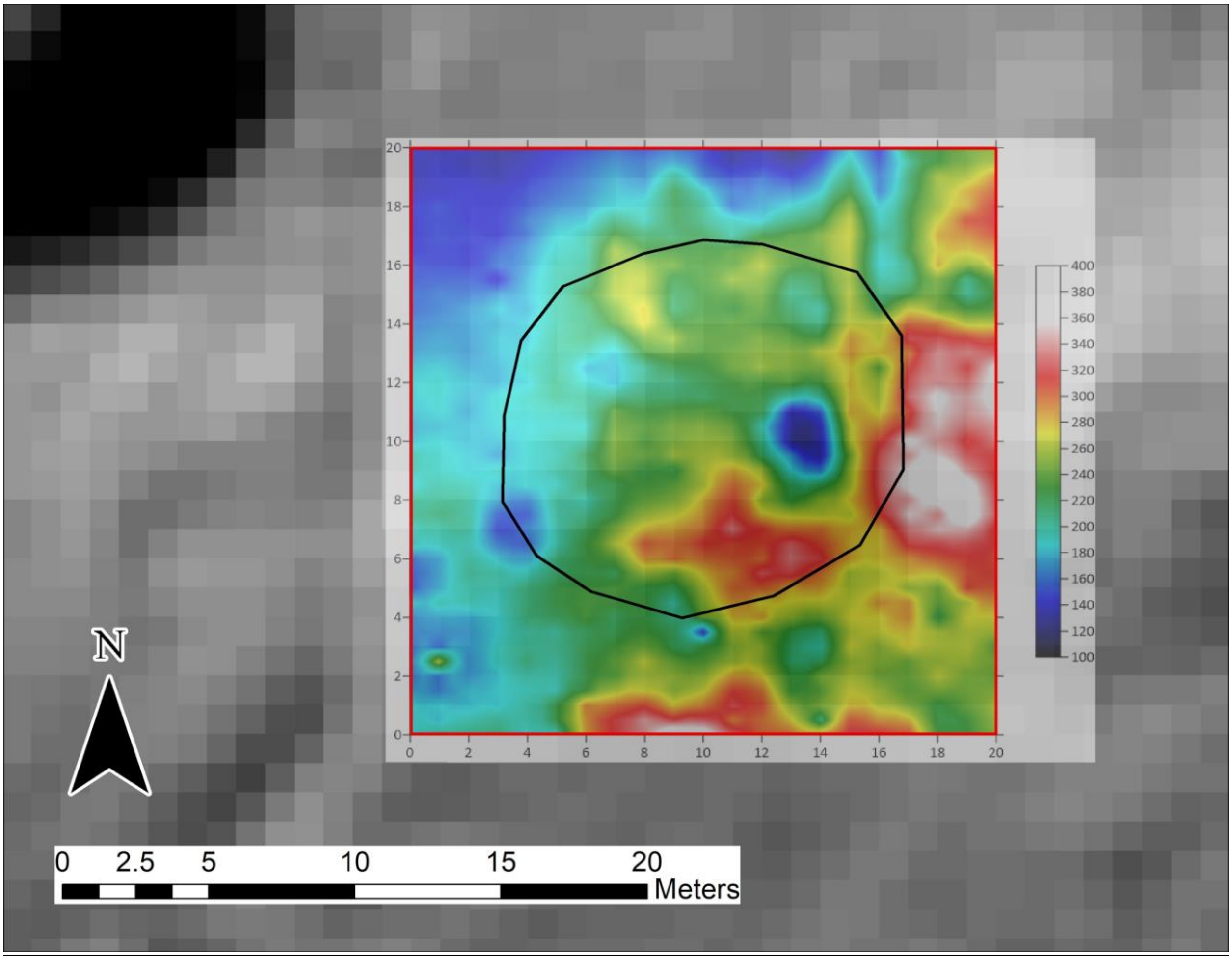

Figure 24: Mapped results at 0.5 meters below the surface of the mound at the Belle Creek site. Grid boundaries are indicated in red while mound boundaries are indicated in black. Resistivity anomalies are visible within the boundaries of the mound, indicating the mound may be composed of material that is physically different from its surroundings.

3.4 Kiwanis Magnetometry

Results of magnetometry grid data collected over the conical mound feature at the Kiwanis site reach about 1m below the surface and show areas of increased or decreased magnetic charge (Figure 25). Cool colored areas represent areas with a slightly negative magnetic influence on their surroundings while warm colored areas represent areas where a positive magnetic influence exists. Areas in black and white indicate areas where readings are respectively intensely lower or higher to a degree of about 20 nanoteslas, indicating the anomalies in this area are producing their own magnetic signature as a result of either a magnetic object or induced magnetism through a chemical process such as burning. Areas in green indicating locations where the difference between the surface and atmospheric readings are similar.

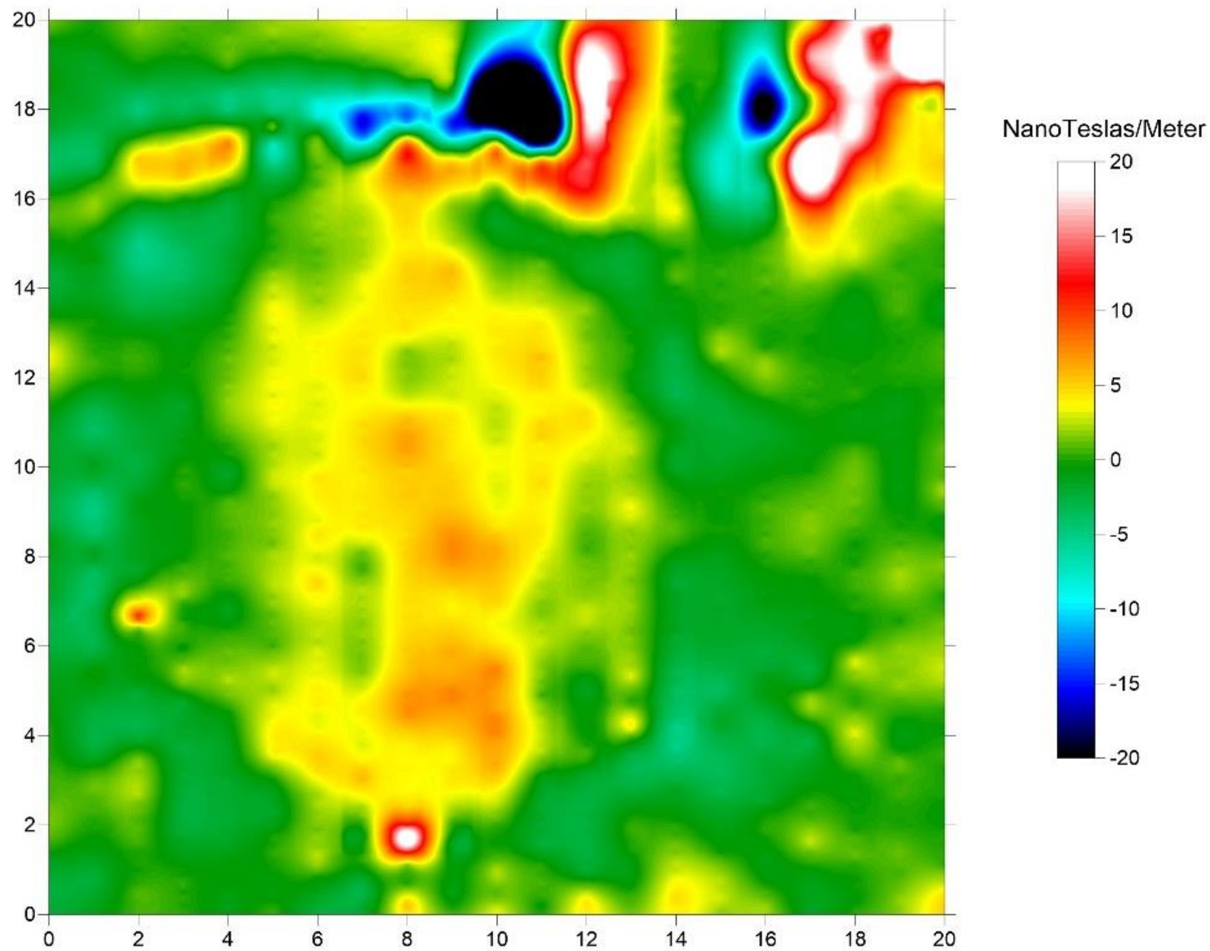

Figure 25: Results of magnetometry readings from 1m below the surface of the Kiwanis mound. Cool colored areas represent areas with a slightly negative magnetic influence on their surroundings while warm colored areas represent areas where a positive magnetic influence exists.

A concentration of comparatively higher magnetic readings is visible within the confines of the Kiwanis feature (Figure 26 in black). This suggests a higher concentration of magnetic material than its surroundings within the mound fill different material than its surroundings at the same depth. Whether this is the result of mixing of materials during the formation of the mound or caused by the introduction of material into the mound fill from elsewhere is uncertain, but it is probable that mound fill is characteristically different from its surroundings. Further, irregular, dipolar anomalies, indicated by side by side black and white readings, are visible towards the top right of the grid. This suggests either the presence of metallic material or remnants of chemical changes to the soil brought about through burning due to the intensity of the readings.

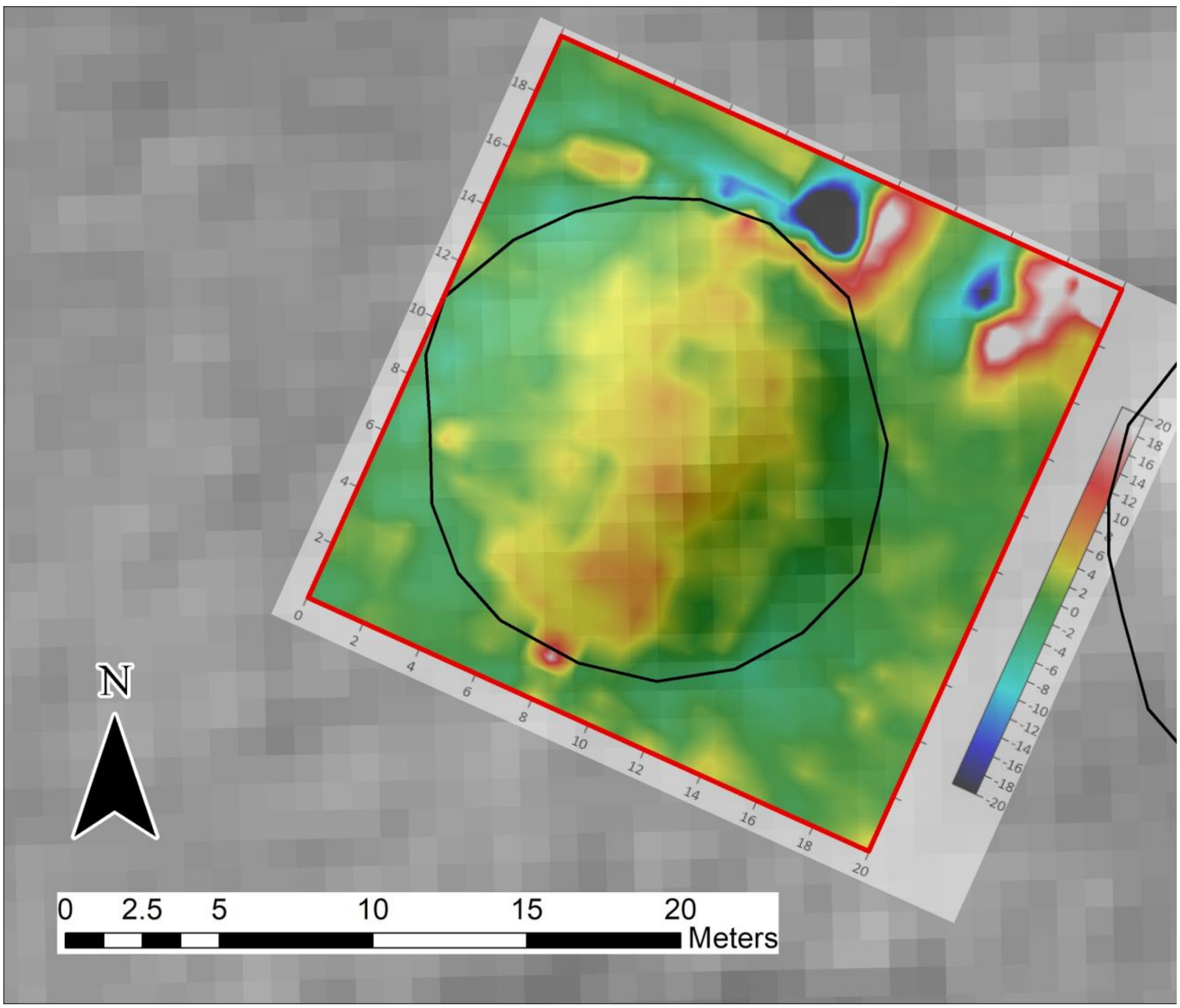

Figure 26: Mapped results at 1 meter below the surface of the mound at the Kiwanis site. Grid boundaries are indicated in red while mound boundaries are indicated in black. Similar to what is seen in resistivity and GPR results, anomalous magnetometry areas fall within the mound boundaries, indicating the mound fill is physically different from its surroundings.

Results of magnetometry grid data collected over the conical mound at the Belle Creek site from about 1m below the surface are visible in Figure 27. Again, cool colored areas represent areas with a slightly negative magnetic influence on their surroundings while warm colored areas represent areas where a positive magnetic influence exists.

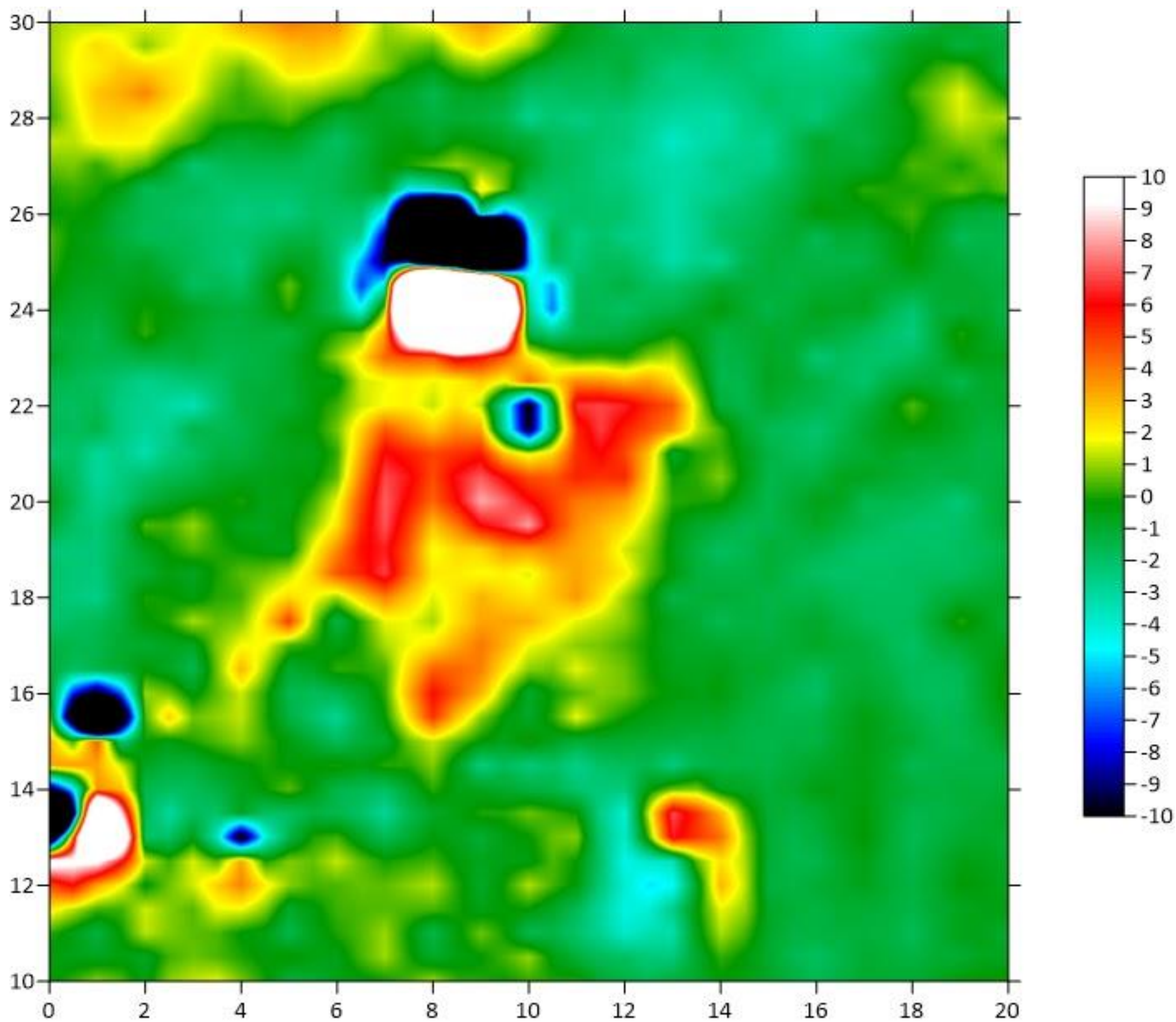

Figure 27: Results of magnetometry readings from 1m below the surface of the Belle Creek mound. Cool colored areas represent areas with a slightly negative magnetic influence on their surroundings while warm colored areas represent areas where a positive magnetic influence exists.

Similar to the readings collected at the Kiwanis site, higher magnetometry readings are concentrated within the confines of the mound, suggesting mound fill is composed of material that is different from its surroundings. Additionally, a dipolar anomaly exists in the northern part of the mound (Figure 28). Examination of results in the field indicated dipolar anomalies in the southwest quadrant of the grid were the result of metal objects and thus could also be leading to the intense magnetic charge in the northern part of the mound.

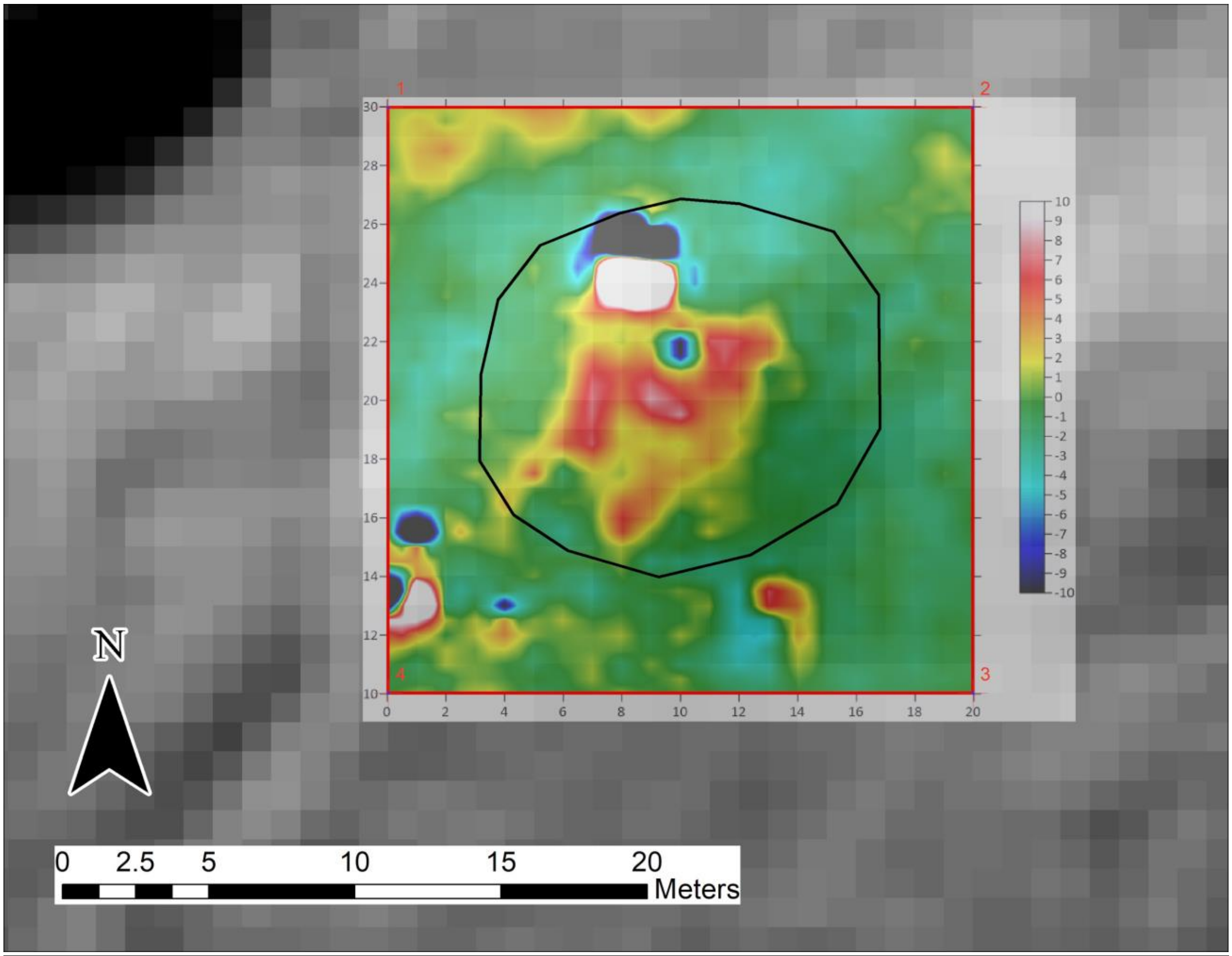

Figure 28: Mapped results at 1 meter below the surface of the mound at the Belle Creek site. Grid boundaries are indicated in red while mound boundaries are indicated in black. Similar to what is seen in resistivity and GPR results, anomalous magnetometry areas fall within the mound boundaries, indicating the mound fill is physically different from its surroundings.

3.5 Summary of Results

The results of the geophysical investigations at the Kiwanis and Belle Creek sites indicate the mound features at both sites share similar physical properties to one another. Transect data collected over both mounds indicates stratigraphic units within the mounds dip away from the mound apex and are semi-continuous or hummocky. GPR depth slices near the base of both mounds suggest that the mound fill contrasts in dielectric constant different from the material that surrounds the mounds. This is further exhibited by electrical resistivity and magnetometer data that additionally indicate the mound fill is characteristically different from the surrounding sediments. In addition to these, the rectangular anomaly oriented towards the cardinal directions visible in GPR data as well as the dipolar anomalies in magnetometry data suggest cultural interaction within and adjacent to the mound at the Kiwanis site at least prior to its formation. Viewed in tandem, these data align more closely to align with suggestions of cultural origins for the mound features at the Kiwanis site.

4.0 Discussion

The limited archaeological data within the Eau Claire area coupled with the existence of natural features that are morphologically similar to mounds constructed by humans is the cause of conflicting hypotheses for the origins of the Kiwanis mounds. The first of these hypotheses states that the mounds formed through natural means followed by being enclosed by a field edge push from modern agricultural practices surrounding the site. This hypothesis can be divided into two separate hypotheses that state the natural origin of the hemispherical features is the result of either aeolian processes forming dome dunes or biogeomorphological processes resulting in mima mounds. If these hypotheses are rejected as a result of data not fitting models of deposition for either phenomenon, their existence must be explainable through cultural means. Native American cultures constructed mounds throughout the southern half of Wisconsin most predominantly during the Middle (500 BCE (2450 BP) to 500 CE (1450 BP)) and Late Woodland (500 CE (1450 BP) to 1200 CE (750 BP)) periods (Arzigian and Stevenson 2005). The location of the Kiwanis site is within the region where mounds were primarily built during these periods and thereby fits a model of cultural origin. Further, if comparisons to data collected at the Belle Creek site indicate the stratigraphy is similar between the two mounds and contain anomalies inexplicable by natural processes, a hypothesis of Native American can be accepted.

It is important to note that if data at the Kiwanis site are ambiguous between models of natural and cultural deposition, a hypothesis of Native American origin can neither be accepted nor denied. Rather, data collected at the Kiwanis site must eliminate the possibility of a natural origin by showing that the patterns and anomalies within collected data do not match a model of natural deposition of sediments for the alternative hypothesis of cultural origin to be accepted. Thus, data from both the Kiwanis site and the Belle Creek site are first examined through a natural lens to determine whether a model of natural or artificial genesis is conceivable. If results do not match a model of natural genesis and are comparable between the two sites, a cultural genesis for the mounds is an acceptable conclusion. Further, anomalies within geophysical data that can be interpreted as cultural would serve to strengthen such an argument.

4.1 Dome Dunes

Claims that the Kiwanis mounds are the result of aeolian deposition stem from the existence of natural features called dome dunes. Dome dunes are hemispherical features that are either the beginnings or the remnants of other aeolian features such as barchan or linear dunes but do not have slipfaces (Ritley and Odontuya 2004, Narteau et al. 2017). Dome dunes are also traditionally found within zones of low sediment availability and what is described as dome dune fields (Narteau et al. 2017). These dune fields (Figure 29) contain a plethora of dome dunes with similar morphologies.

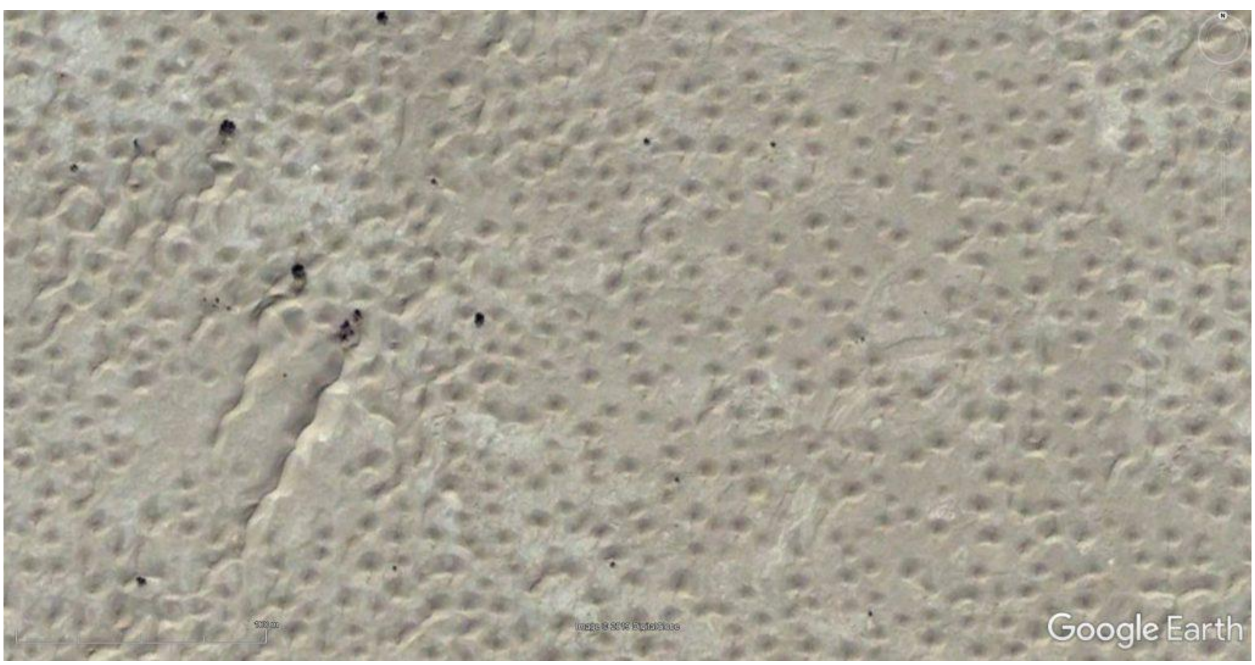

Figure 29: Google Earth image of a dome dune field in Kazakhstan (45°46'56.4"N 60°53'48.5"E). Dome dunes are often found in dune fields such as these that can contain

hundreds to thousands of dome dunes at a time. If the mounds at the Kiwanis site are aeolian features, they are astoundingly isolated.

With this in mind, the location of the mounds at Kiwanis does not match the setting within which dome dunes are found. Rather, the mounds at the Kiwanis site would be exceptionally isolated in comparison to a dome dune field and in an area of high sediment availability, evident from the size of the nearby parabolic dunes (Millett 2019).

Additionally, when examining the internal stratigraphy of the hemispherical feature at the Kiwanis site (Figures 30 and 31), it does not match what would be expected if they were dome dunes. Rather, the stratigraphy of the mounds at the Kiwanis site not only contains discontinuous and hummocky bed forms, but a dipping of bedforms in all directions. These data contradict what would be expected if the mounds formed through aeolian processes. Were it to be that the mounds formed through dome dune processes, these bedforms would not be as uniform as they appear, if extant at all. Millett 2019 showed that the sand sheet immediately below the parabolic dunes and the mounds at the site, along with the parabolic dunes themselves, are the result of winds from a south-southeasterly direction and deposited as parabolic dunes near the cliff-escarpment (Figure 32).

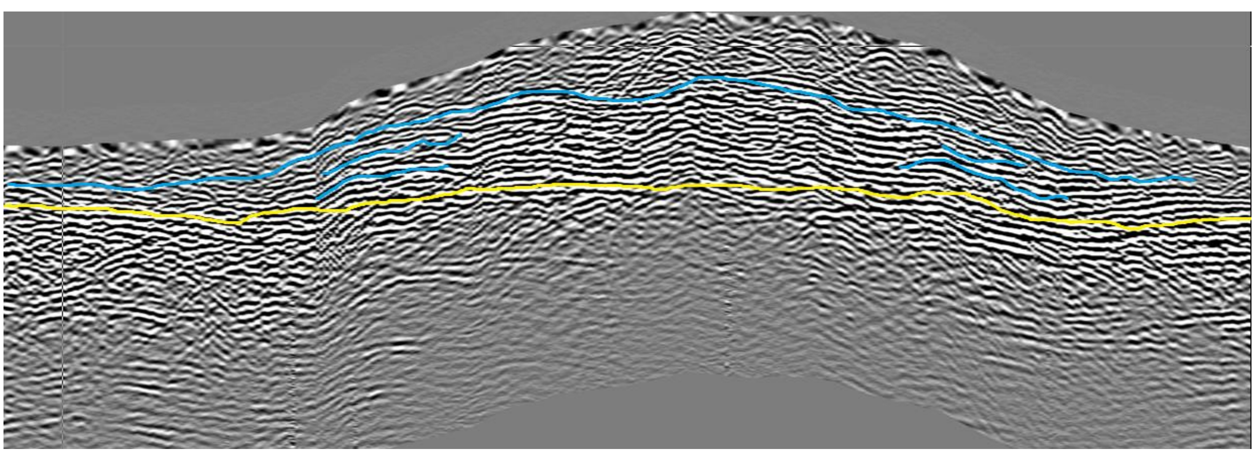

Figure 30: GPR transect running northwest to southeast over the center of the Kiwanis mound. Blue lines highlight the orientation of the reflections within the mound, illustrating they dip away from the mound apex. The yellow line indicates the base of the mound.

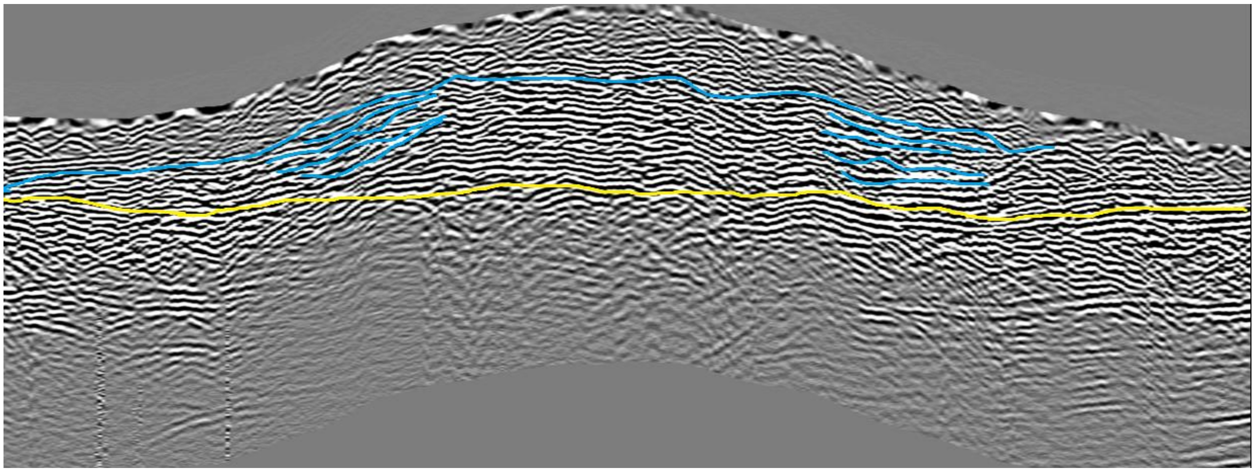

Figure 31: GPR transect running northwest to southeast over the center of the Kiwanis mound. Blue lines highlight the orientation of the reflections within the mound, illustrating they dip away from the mound apex. The yellow line indicates the base of the mound.

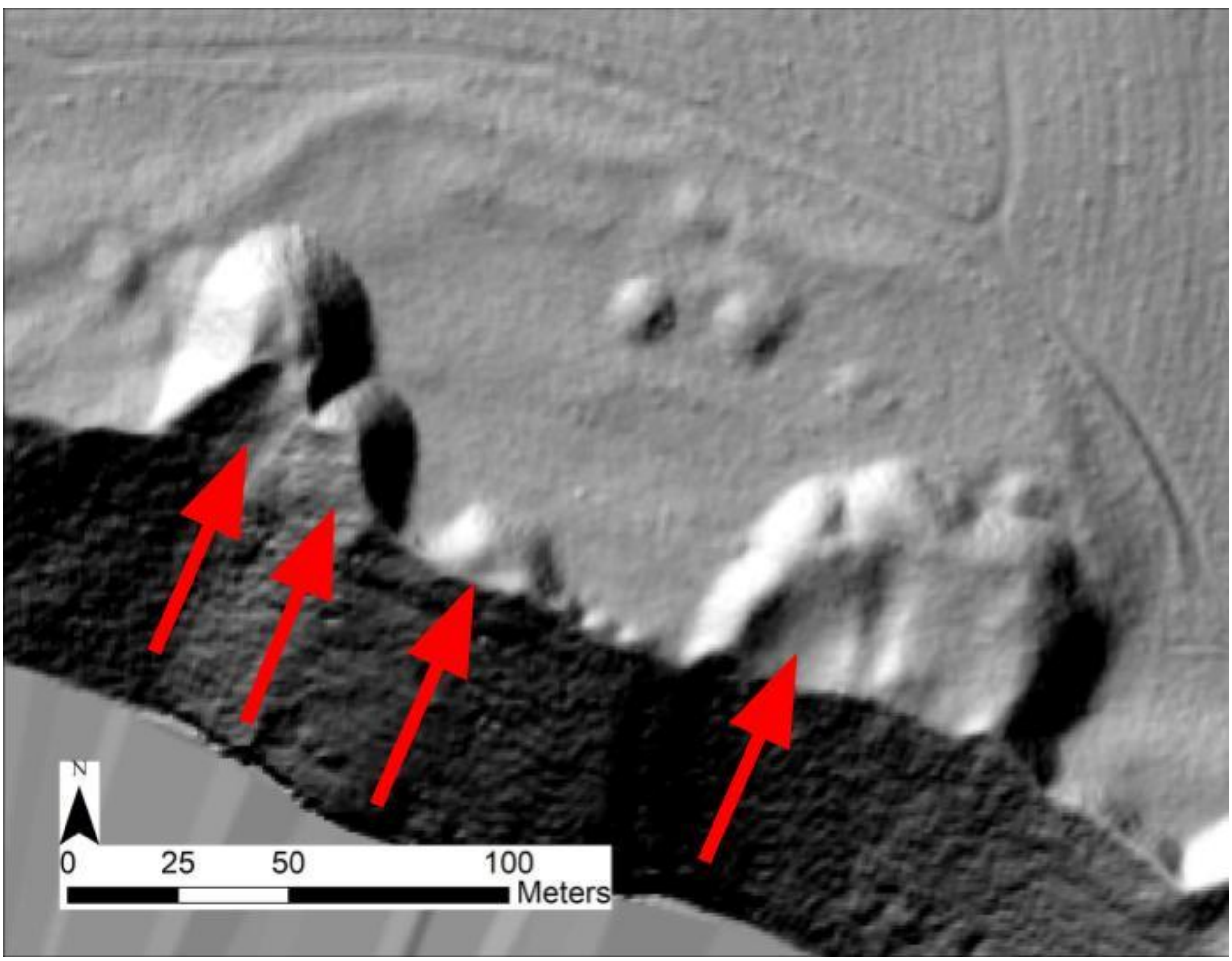

Figure 32: LiDAR image of the Kiwanis site with red arrows indicating the direction of winds responsible for forming the sand sheet and cliff top dunes at the site.

The time frame within which aeolian processes could result in dome dunes at the Kiwanis site also does not match chronologic data collected at the site. Schaetzel et al 2018 describes two aeolian deposition events resulting in a thin layer of sand described as a sand sheet, followed by the large parabolic dunes in clifftop position adjacent to the mounds at the Kiwanis site. Deposition of these features occurred around 9kya and 1kya - 500ya, respectively, according to OSL dates gathered by Millett (2019). This constrains the dates between which the mounds could have been deposited through aeolian processes to between these dates or after the deposition of the parabolic dunes given the mounds are on top of the sand sheet and directly adjacent to the parabolic dunes. For the former to have occurred, winds would initially have to come from the southwest, shift course and originate from multiple directions during the time between 9kya and 1kya, and then shift back to originating from the southwest at around 500ya. If aeolian deposition of dome dunes were to have occurred after the formation of the parabolic dunes, winds would have to shift to multi-directional following 500ya. However, evidence of such changes in wind direction would be seen in both the mounds and the parabolic dunes were this to be the case. The data clearly contravene this expectation. Dome dunes would have been obliterated during the deposition of the parabolic dunes given the strong winds responsible for forming them. Similarly, the proximity to the dunes would have resulted in changes to their parabolic shape if multi-directional winds formed the dome dunes.

Aeolian deposition of materials also would not account for the increase in magnetism, electrical resistivity, and contrast in dielectric constant seen in geophysical depth slices. While such results could be caused by multiple periods of deposition and soil formation (Kvamme 2006, Smekalova et al. 2008, Loke 2004), the Kiwanis site has, at present, evidence of only two periods of aeolian deposition with the sand sheet and cliff-top dunes at the site (Schaetzl et al.

2018, Millett 2019). Thus, not only does the stratigraphy of the Kiwanis site not match a model of what would be expected for dome dunes, but it does not match a model of aeolian deposition. Given the unidirectional nature of winds that deposited the nearby parabolic dunes and sand sheet, a similar pattern would be expected within the mounds themselves. This coupled with the fact that the mound fill itself is different from its surroundings to a high degree indicates an aeolian deposition for the hemispherical features at the Kiwanis site does not explain their genesis.

4.2 Mima Mounds

The other explanation of a natural origin for the features at the Kiwanis site is that they are mima mounds, hemispherical features constructed by burrowing creatures such as gophers as they dig their burrows. Mima mounds are found almost exclusively west of the Mississippi River and are hemispherical features roughly 1m above the ground. They are most often found in mound groups of hundreds of mounds, but can be in the thousands in some cases (Figures 33 and 34) (Washburn 1988, Johnson and Burnham 2012, Gabet et al 2014). The internal stratigraphy of these features is entirely unstratified as the animals responsible for these features do not uniformly deposit sediments they propel from their burrows as they dig them.

With these characteristics in mind the mounds at the Kiwanis site cannot be explained as being Mima mounds as they would have to be the work of a methodical, lone gopher or other burrowing creature. The fact that the height of the mounds at the Kiwanis site is greater than 2m, the presence of a distinct stratigraphy, as well as the relatively isolated state of the mounds in comparison to what is seen in mima mound fields, disproves this hypothesis. Although it could still be argued that the mounds at the Kiwanis site are the remnants of a mima mound field, such a suggestion ignores the stratigraphy present within the mounds. GPR transects collected at the

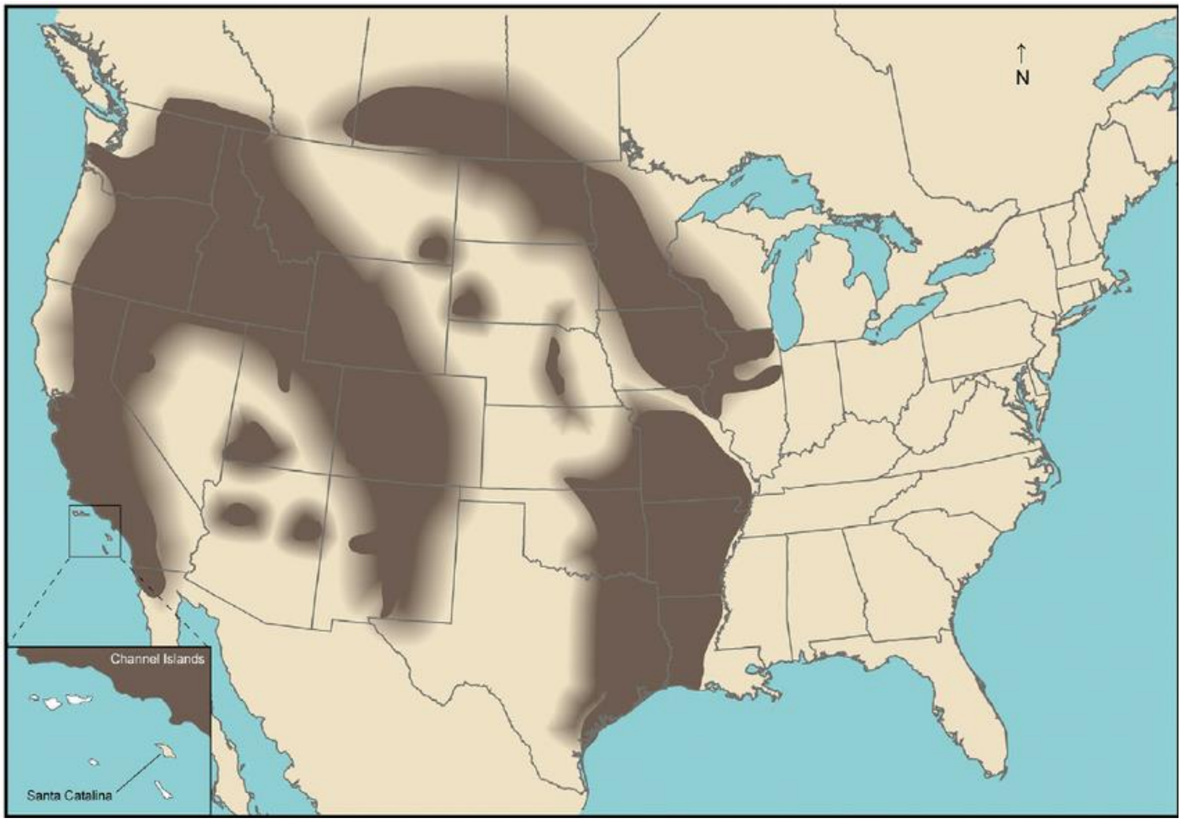

Figure 33: Map of the distribution of mima mounds within the US (dark brown) (Johnson and Burnham 2012).

Figure 34: Image of a set of mima mounds located in Washington State (Washington State DNR). If the mounds at the Kiwanis site are mima mounds, they would be astoundingly isolated, similar to if they were dome dunes. Further, the existence of only five mounds instead of the expected hundreds of mounds that are found in mima mound fields would suggest the mounds were formed by a lone or pair of gophers setting off on their own.

Kiwanis site (Figures 32 and 33) in both north-south and west-east directions at the Kiwanis site contain reflections that dip in respective directions away from the mound apex that suggests a distinct process of formation as opposed to haphazard deposition of sediments. This is comparable to those collected at the Belle Creek site and are likely the result of construction processes such as basket loading (Arzigian and Stevenson 2005). Further still, the location and frequency of the mounds at the Kiwanis site do not reflect what would be expected. If the Kiwanis mounds are indeed the remnants of a mima mound field, similar features would be expected to be seen in high concentration within the greater vicinity of the Kiwanis mounds. Thus, a natural model of formation for the mounds at the Kiwanis site cannot be used to explain their origins.

4.3 Field Edge Push

In addition to a natural explanation being provided for the hemispherical features at the Kiwanis site, it has also been suggested that the linear features at the Kiwanis site are the result of agricultural processes leaving behind a field edge push. A field edge push is a linear ridge at the end of an agricultural field that forms when the soil is scraped and flattened for agricultural purposes, or when many years of unidirectional plowing results in sediment buildup at the lateral margins of the field. Such a feature is visible within LiDAR imagery at the Belle Creek site (Figure 35) as a distinctly linear rise along the edge of the agricultural area. Thus, in future studies of the site, the origins of the linear features surrounding the hemispherical mounds at the site may be determined based on whether an internal stratigraphy is present or not.

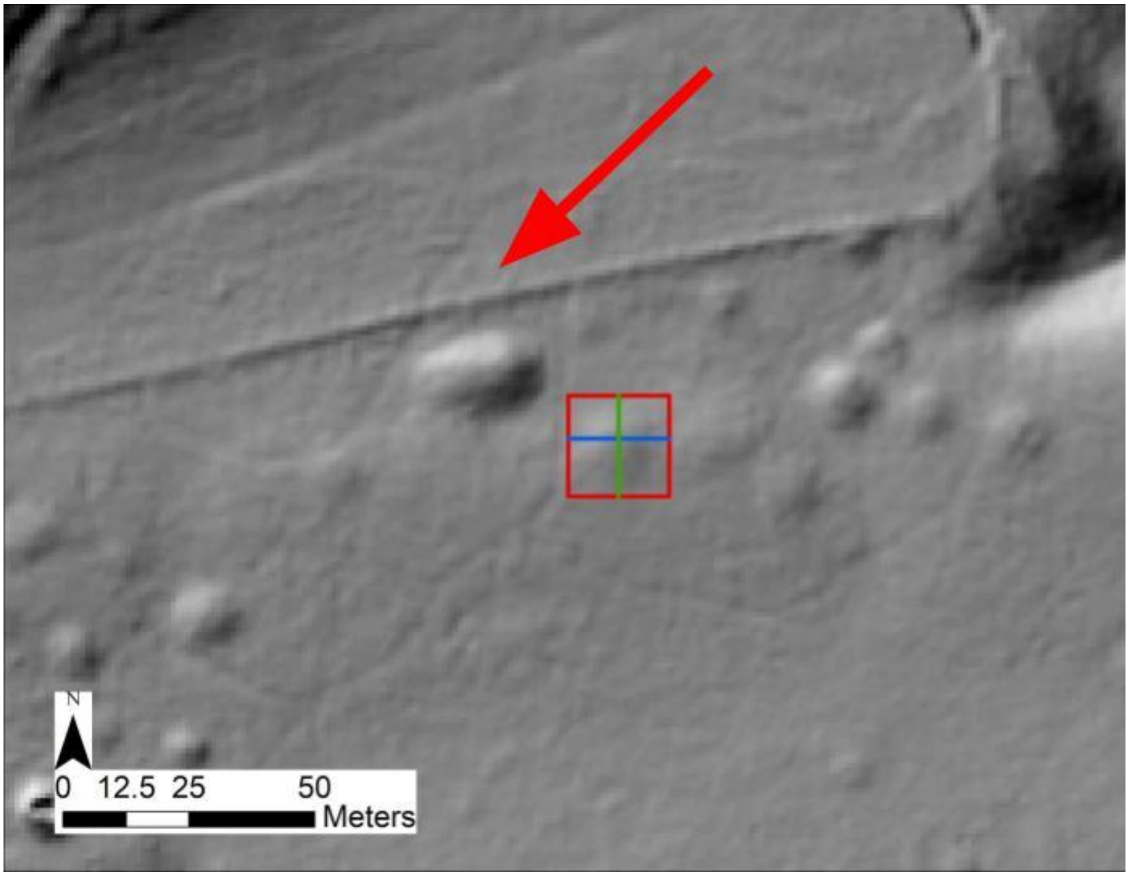

Figure 35: LiDAR image of the Belle Creek site with an arrow pointing to the unnaturally straight linear feature at the site described as a field edge push. This field edge push is noticeably more uniform and deliberately lines the edge of the field, rather than the diffuse shape of the linear features at the Kiwanis site that appear to enclose the mound and dune features and do not line the edge of a field.

However, the hypothesis of the linear features at the site being the result of agricultural practices is inadequate based on their morphology alone. The dimensions of the linear features at the site are roughly 120m long, 10m wide, and 2m high, while the field edge push at the Belle Creek site is 262m long, 3m wide, and roughly 50cm high, running along the southern edge of the entire field. A similar pattern would be expected if the linear feature at the Kiwanis site were a field edge push. Yet, the dimensions of the linear features are not similar to a field edge push and the perfectly symmetrical angles midway between both of the two features appears to purposefully enclose the hemispherical features at the site. Thus, the morphology of the linear features is not consistent with what would be expected for a field edge push, being much more diffuse and irregular. However, as stated, proof of this could come from future studies of the internal organization of the linear features.

4.4 Native American Origins

While the results of geophysical investigations of the mounds at the Kiwanis site do not match a discussed model of natural genesis, they do reflect what would be expected if they were constructed by humans through means such as basket loading. The location of the mounds fits what would be expected of mounds in the area around the Kiwanis site being that they are atop a terrace and along a prominent river within the geographic area where mounds were most commonly constructed during the Late Woodland. Further, the stratigraphy exhibited by GPR data from within the mounds coupled with depth slices from GPR, electrical resistivity, and magnetometry data indicate that the mounds are composed of layered material that is characteristically different from its surroundings. Most notable, though, is the presence of anomalies within and abutting the examined hemispherical mound at the Kiwanis site. These features coupled with the geophysical properties of the mound and the inability for data to be explained through the investigated natural processes suggests that the mounds are indeed cultural.

Mounds constructed during the Late Woodland period were mostly constructed in the southern half of Wisconsin (Highsmith 1997, Birmingham and Eisenberg 2000, Birmingham and Goldstein 2005). In addition to this, they were often constructed atop high points along prominent rivers within this region. Given the fact that the Kiwanis site is located within the southern part of Wisconsin, on top of the Wissota Terrace, and along the Chippewa River, the location of the mounds is not unique to what was common for mounds constructed during the Late Woodland. However, as evident by the reason this project exists, this point is not enough to conclude that the Kiwanis site is cultural in origin. Rather, it serves to strengthen the conclusions presented by the data collected at the site.

GPR transects collected over the mound illustrate not only a layering of sediments within the mound fill, but also suggest they may have been deposited by construction processes such as basket loading. This method involves the collection and, as a result, mixing of materials for mound construction in baskets. This material is then transported to the mound construction site and deposited, forming the mound fill (Arzigian and Stevenson 2005). This is visible by the wavy nature of the reflections (Figure 36). During this process, individuals constructing the mounds collect mound fill material in baskets, progressively dumping them atop the mound location until any internal components are buried and the mound reaches the preferred height. Such a process could also explain the sloughing of the material seen in GPR transects. Sand topples downslope when the angle of repose is breached. Continual piling of material to form a mound would reach such an angle constantly throughout the construction process and cause material to slough away from the mound apex on all sides, as seen in GPR transect data. Indeed, a similar pattern in transect data to what is described is seen from data collected at the Belle Creek site. Given the known cultural origin of the Belle Creek site, the absence of evidence of natural origins of the Kiwanis mounds, and the similar pattern exhibited in transect data between the two sites, data suggest that the stratigraphy within the mound of the Kiwanis site is the result of construction processes similar to those practiced by Native American peoples. Outside of the stratigraphic patterning of the mound fill, though, the physical properties of the soils exhibited in electrical resistivity and magnetometry data additionally provide credence to an argument of cultural origin. Mound fill is most often either sourced from nearby or immediately surrounding mound bases at mound sites, however multiple instances of colored soil lenses from outside the

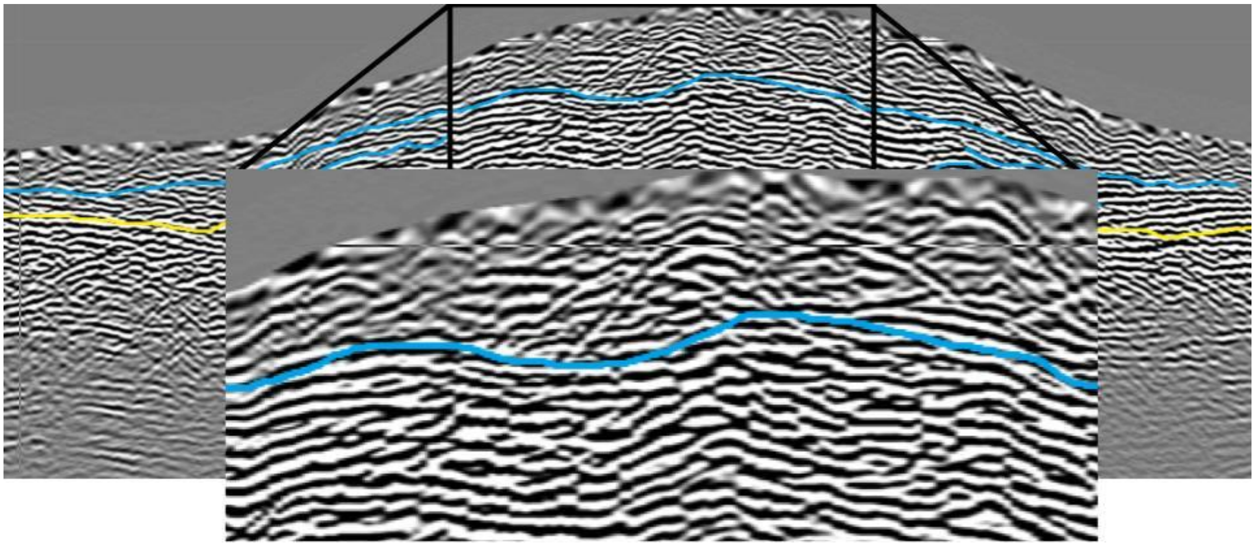

Figure 36: GPR transect data collected over the mound at Kiwanis running from North to South. Undulating stratigraphy within the mound, seen in blue in the zoomed in portion of the image could be the result of basket loading.

locality of the mound or the inclusion of a charcoal lens have been documented as well (Highsmith 1997, Birmingham and Eisenberg 2000, Arzigian and Stevenson 2003, Birmingham and Goldstein 2005). Electrical resistivity data indicate an increase in resistivity within the central southern portion of the mound and could be the result of such a construction process leading to less compaction in this portion of the mound. However, magnetometry and GPR data most readily reflect this. The increase in magnetometry within the boundaries of the mound and a relative decrease in the areas surrounding the mound at the Kiwanis site would most likely be the result of material from the subsurface being brought to or mixed with material nearer to the surface. Mixing of remnant magnetic charges and iron content in differing sediment layers as the materials are gathered and piled to form the mound could produce the distinctly high magnetic reading within the mound fill (Kvamme 2006, Smekalova et al. 2008). This process, too, would explain the increase in electromagnetic reflection seen in GPR results as changes in subsurface materials and the mixing of such materials could explain why an increase in reflection intensity is exhibited within the mound boundary. Further, if construction of a mound leads to less compaction of the mound fill, moisture within the mound fill could also result in such a disparity.

Instances where material from outside of the mound site have been observed as well, and could also explain the increase in GPR energy within the mound boundary. Such instances could be due to an attachment to a particular place important to the person or entity the mound is constructed for, and thus necessary for inclusion within the mound fill (Birmingham and Eisenberg 2000, Birmingham and Goldstein 2005, Arzigian and Stevenson 2005, Fagan 2005). For example, thin layers of clay or charcoal have been noted in multiple mound excavations in the past that could serve a ceremonial or structural purpose in mound construction. If such a layer is present in the Kiwanis mound, it would explain the intensity of the reflection in GPR depth slices. Such patterns are similarly visible in the mound at the Belle Creek site. Yet, it is important to note that it cannot be accurately determined precisely what differences are causing mound fill to be characteristically different from the surrounding sediments without invasive investigations. Instead, the fact that geophysical data indicate moundfill is different from the surrounding sediments and are not explainable through natural models of sediment deposition provides credence to the mounds being cultural in origin.

However, the most definitive evidence of cultural origins for the mounds is a pair of two dipolar magnetic anomalies just northeast of the mound and a rectangular anomaly towards the center and oriented towards the cardinal directions in GPR depth slices at the Kiwanis site (Figures 37 and 38). Such anomalies are the most direct evidence of a prehistoric cultural component to the Kiwanis site, especially when viewed in tandem with the stratigraphic and physical properties of the Kiwanis mound and Belle Creek mound. A dipolar anomaly in magnetometry data is a location within the data where the magnetic signature of the subsurface is markedly different, both negatively and positively, from the surrounding readings. These anomalies, seen in Figure 37, are visible as two abutting black and white readings at the top of the survey grid. Dipoles such as these are caused either by the presence of metallic objects or caused by intense heat reorienting the magnetic declination of iron particles within the soil (Kvamme 2006, Smekalova et al. 2008).

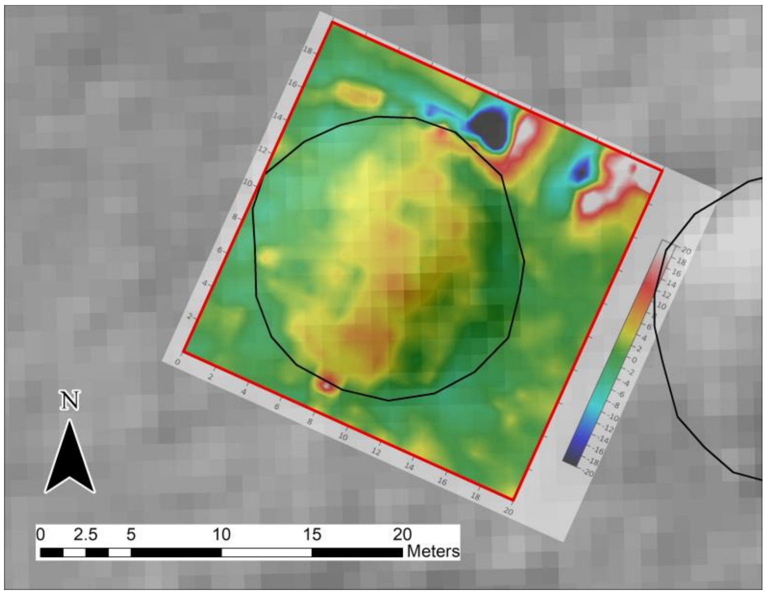

Figure 37: Magnetometry data from the Kiwanis mound overtop LiDAR data. Magnetic dipole anomalies, created due to processes such as burning, are visible as black and white blobs directly northeast of the mound boundaries (in black).

A dipole such as the anomaly visible in magnetometry data is more closely associated with the latter example as metallic objects tend to create a doughnut shaped dipole rather than a side by side anomaly as visible in the Kiwanis data. While these dipoles could be the result of a natural burning process such as a fire caused by a lightning strike, the size and proximity of the dipolar anomalies are likely the result of a man-made fire. However, excavation would be required in order to definitively determine the nature of these anomalies and the purpose a human made fire in this vicinity would have served.

The presence of a rectangular anomaly within GPR slices suggests the presence of a burial feature within the mound (Figure 38). This due to the dimensions of the anomaly measuring roughly 2m x 4m x 0.5m and its orientation being north-south. Burial features in mounds throughout the Midwest often include rectangular structures within which a single individual or multiple individuals are interred (Birmingham and Eisenberg 2000, Birmingham and Goldstein 2005, Arzigian and Stevenson 2005, Fagan 2005). These features were often oriented towards the cardinal directions or astronomical events such as the solstice (Birmingham and Eisenberg 2000, Birmingham and Goldstein 2005, Arzigian and Stevenson 2005). Evidence of both of these characteristics within the center of the mound at the Kiwanis site suggests human behavior and reasoning behind the orientation of the anomaly.

While the distinctly cultural features visible in geophysical data at the Kiwanis site are not present in data at the Belle Creek site, the fact that the physical properties and mound stratigraphy is comparable between the two sites is key to interpreting the origins of the mounds at the Kiwanis site. When this along with the likely cultural anomalies and previously discussed arguments against a natural or historical genesis are viewed in conjunction, evidence best fits a model of cultural origin for the Kiwanis mounds.

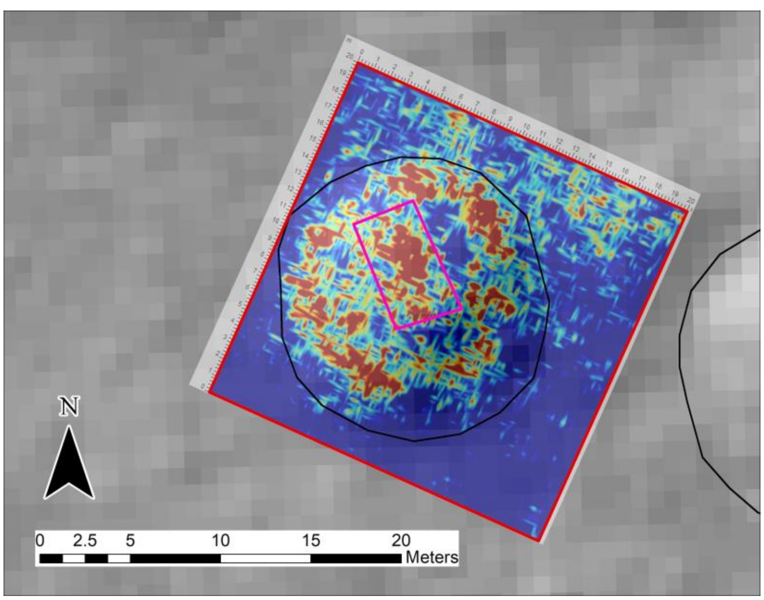

Figure 38: GPR Depth slice from 1.5m below the surface at the Kiwanis site overtop of LiDAR data. A rectangular anomaly (in pink) is visible near the center of the mound at this depth and is oriented to the cardinal directions

5.0 Conclusions

The results of data collected at the Kiwanis site indicate that it is indeed cultural in origin and is most likely related to the Late Woodland period of Native American history. If they were dome dunes or mima mounds, their context in the landscape and relative isolation compared to the dune and mound fields in which they are usually found would make them markedly isolated. Such isolation is not unique for the case of hemispherical Native American mounds found throughout Wisconsin, however. Mounds were often constructed atop highpoints along major rivers, meaning the location of the mounds at the Kiwanis site fit this description (Birmingham and Eisenberg 2000, Birmingham and Goldstein 2005, Arzigian and Stevenson 2005).

Stratigraphy present in the examined mound at Kiwanis does not match what would be expected from instances of natural deposition such as dome dunes or mima mounds. In these cases, stratigraphy would respectively be horizontal or nonexistent. Stratigraphy within the mound at the Kiwanis site does not show either of these, instead exhibiting hummocky stratigraphy that dips away from the mound apex. Further, this pattern is similar to the stratigraphy exhibited in the mound from the Belle Creek site, a mound of known cultural origin.

Slice data from electrical resistivity, magnetometry, and GPR grid data indicate an increase in electrical resistivity, increase in magnetic signature, and high contrast in dielectric constant of the mound fill. These readings are characteristically different from their surroundings and all could be brought about by the unavoidable mixing of materials as the mound is constructed. Additionally, these results compare to the Belle Creek site as well.

The most definitive evidence, though, of a cultural origin for the Kiwanis mounds comes from distinct, unnatural anomalies in magnetometry and GPR slices. The pair of magnetic dipoles next to the mound at the Kiwanis site indicate that something was burned there based on the North-South alignment and intensity of the anomaly. The rectangular anomaly within the center of the mound is oriented towards the cardinal directions, similar to what was done in other burial mounds (Birmingham and Eisenberg 2000, Birmingham and Goldstein 2005, Arzigian and Stevenson 2005, Fagan 2005).

By viewing these individual portions of evidence as a whole, I interpret the Kiwanis site is a cultural site. However, it should be noted that this can only be proven for certain if the mounds are excavated and artifacts are found. This will not be done out of respect for the individuals that could be interred within the mounds, their descendents, and in accordance with federal law (NAGPRA 1990). Yet, the fact that the data from the Kiwanis site do not match a natural model for deposition, are similar to data collected over a known cultural mound, and indicate the existence of anomalies within the mound that strongly point artifactual material all but eliminates the need for such destructive processes and demonstrate the utility of similar, multimethod geophysical investigations in other mound sites of questionable origin. With this in mind, further interpretations can begin to be made as to the significance of the site as well as ideas of how the project can be built upon in the future.

5.1 Significance of the site: Thunderer Effigy?

Having proven the origins of the Kiwanis site as cultural, focus can begin to shift towards the site as a whole by analyzing the possibility that the mounds are not distinct, unrelated features but the components of a large effigy. Bird effigies are often the largest constructed earthworks and are associated specifically with the Late Woodland period (Birmingham and Eisenberg 2000). Millett (2019) determined that the large parabolic dunes in clifftop position at the site began forming during the Late Woodland (roughly 1000 C.E.) and may have formed in an abrupt deposition event. With these points in mind, it seems possible that the mounds at the

Kiwanis site may be organized as an effigy to the upperworld being known as the Thunderer (Birmingham and Eisenberg 2000). Petroglyphs and pottery from the Late Woodland subsequent Oneota periods contain depictions of the Thunderer similar to what is seen at the Kiwanis site, such as linear inscriptions representing the wings of the Thunderer and punctates representing the chest (Figure 39). Further, these decorations are not always depicted together as a whole, but sometimes exist separate from one another (Figure 40). Artistic depictions such as these are also not confined to pottery and can often be seen in geoglyphs and earthworks. Thus, the mounds at the Kiwanis site may reflect this on a large earthwork scale, with the linear mounds representing the wings of the Thunderer and the hemispherical mounds enclosed by the linear mounds could represent the chest of the Thunderer. Further, the mounds could have been constructed in response to the formation of the dunes as such a dramatic, landscape shaping event would certainly have been observable, impressive, and highly unusual to any onlooker. Such an event would therefore likely have been memorialized. This is especially due to the strong winds, associated with the upperworld (Birmingham and Eisenberg 2000), responsible for the formation of the dunes. However, elaboration on these interpretations is beyond the scope of this thesis. Yet, they represent the need for further investigations of the significance of the Kiwanis site.

5.2 Suggestions for Future Work

Further work at the Kiwanis site needs to be done in order to fully understand its significance. For instance, determining the date that the mounds were constructed as well as definitively determining the origins of the linear features at the site may aid in understanding the ritualistic implications at the site. Determining the age of the Kiwanis site could come from the use of optically stimulated luminescence (OSL). OSL is a dating technique utilized in Earth

Science to determine the last time individual grains of either quartz or feldspar were exposed to the electromagnetic radiation produced by the Sun (Rittenour 2014).

Figure 39: Vessel found at the Bryan Site near Red Wing, MN, with a full depiction of the Thunderer. Image courtesy of Dale R. Henning.

Figure 40: Image of a vessel found at the Mero site near Red Wing, MN. The punctates enclosed by chevrons along the shoulder of this vessel reflect the tail of the Thunderer. This type of abstracted representation of the Thunderer was not limited to pottery, and could be represented at the Kiwanis site. If so, the wings of the Thunderer would be represented by the linear enclosure mounds while his chest would be represented by the individual mounds.

Ages are calculated by measuring the intensity of luminescence of the sand grains caused by radioactive particles from surrounding minerals becoming trapped within the crystalline structure of the sand grains. Several archeological investigations have utilized the OSL method of dating in recent years, including Feathers 1997; Aiuvalasit 2007; Hodson 2015; and Pluckhahn and Thompson 2017. However, investigations on the utility of OSL in investigations of Midwest earthworks are absent. Thus, the Kiwanis site could serve as a case study for the utility of this dating method in future mound studies. Further, the data collected for this thesis can be used to ensure burial features within the mound at the Kiwanis site are avoided for collection of OSL samples, if okayed by descendent communities. These dates could then be used to better understand the time when the mounds were constructed and be compared to dates from the nearby parabolic dunes to determine if the mounds were constructed before, during, or after the formation of the dunes.

OSL investigations could also be applied to the linear features at the Kiwanis site to determine their relationship to the hemispherical features. Given that hemispherical mounds were also constructed prior to the Late Woodland period, it is possible the hemispherical features at the site predate the linear features by hundreds of years. However, these investigations will also require the application of a similar suite of geophysical surveys to ensure that no burial features exist within where samples will be taken. Evidence of burials throughout linear features has been observed in previous investigations (Arzigian and Stevenson 2003) and thus is entirely possible to be within the linear features at the Kiwanis site given the presence of such features in the hemispherical mound. Further, such investigations of the linear features could aid in scientifically refuting claims that they are field edge pushes.

If OSL dates prove successful and indicate that the mounds were constructed prior to formation of the dunes, further investigations of the dunes themselves may be necessary to ensure the dunes did not bury other mounds at the site. Indeed, LiDAR imagery from the Kiwanis site (Figure 41) contain what appear to be hemispherical features being partially overlapped by the dunes. Thus these investigations may be necessary regardless of OSL dates and could be conducted with the use of GPR.

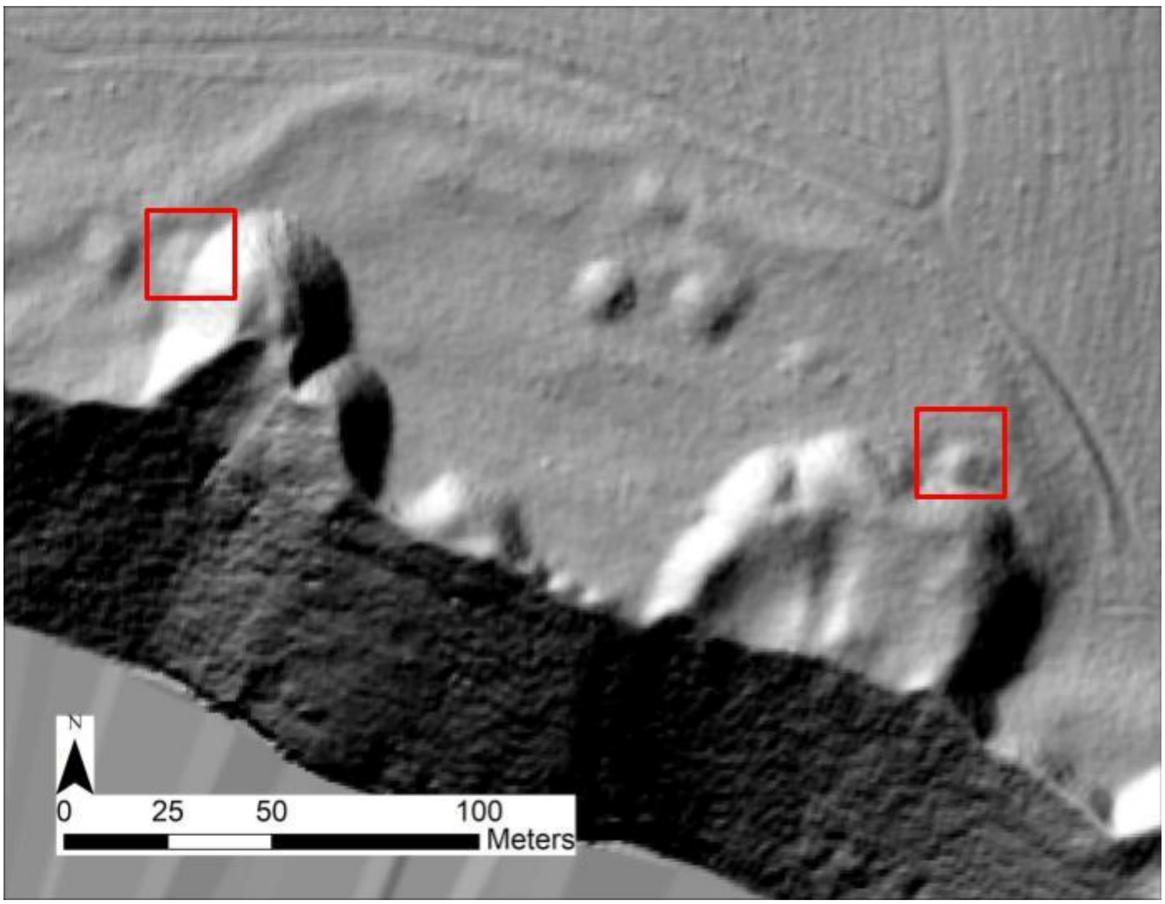

Figure 41: LiDAR image with possible, partially buried mounds at the Kiwanis site. Further studies related to the dates the mounds were constructed and whether they were built after, during, or before the formation of the parabolic dunes could provide insight into if mounds are buried by the dunes at the site.

Besides the mounds and dunes at the Kiwanis site, further investigation of the flat, open area just south of the mounds at Kiwanis and between the large parabolic dunes is also necessary. Mound complexes often contain village or ritual areas within the vicinity of the mounds (Birmingham and Eisenberg 2000, Birmingham and Goldstein 2005, Arzigian and Stevenson 2005). Belle Creek, for example, likely contains a village in the area south of the mound complex (Figure 42), as evident by the presence of pottery in shovel tests conducted at the site (Anton 2021). The flat area within the Kiwanis site could thus contain similar features which could be found using the same geophysical suite applied to the mounds at the site.

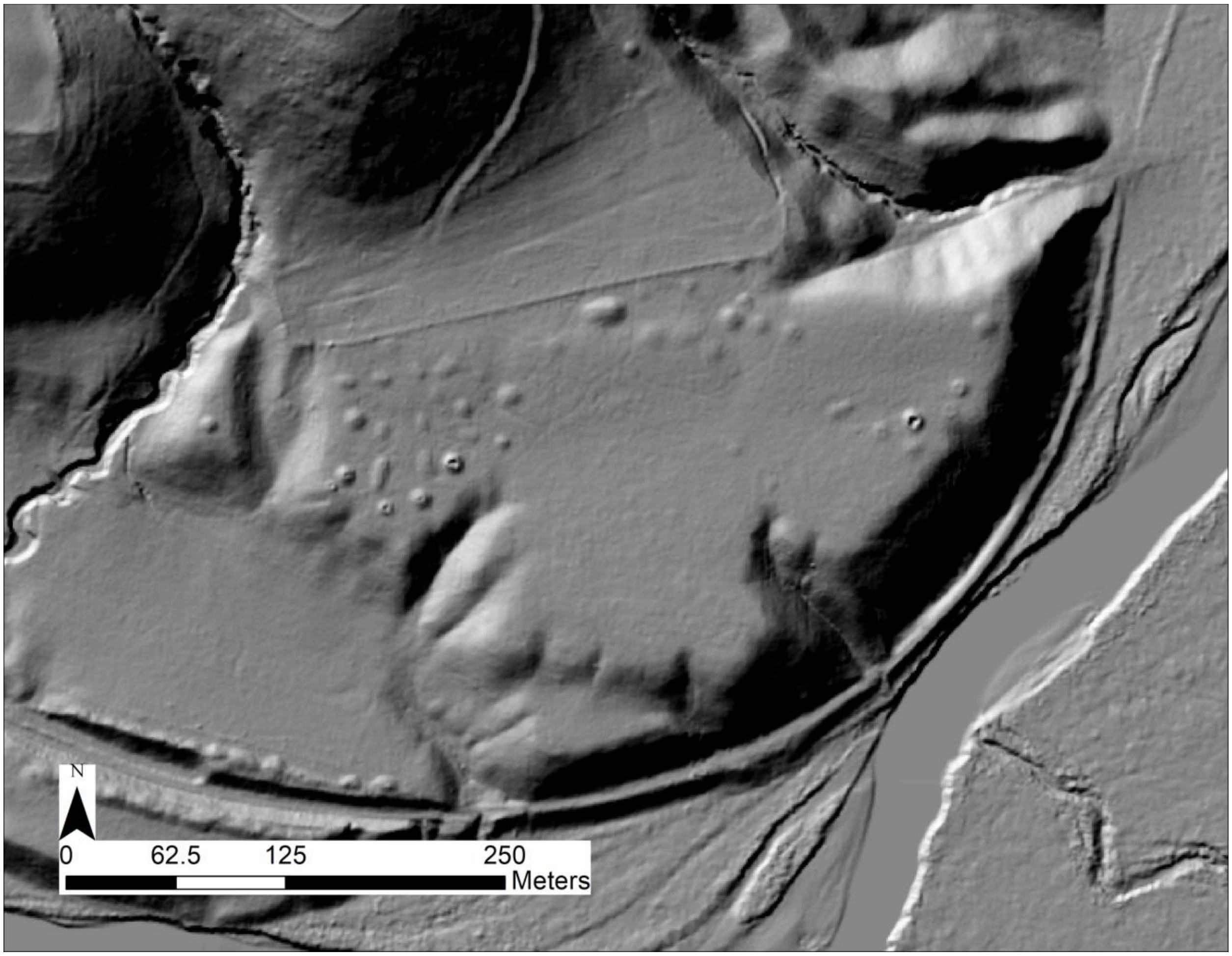

Figure 42: LiDAR image of the Belle Creek site. With the way the mounds seem to encircle the terrace to the south, it is likely a village or ritualistic area exists there. This could be what is happening at the Kiwanis site as well and thus should be studied further, perhaps with a similar suite of geophysical methods.

Despite the need for continued work at the Kiwanis site, the geophysical investigations of the hemispherical features at the site presented in this thesis have provided a basis on which further work can be built. Not only have these investigations concluded that a cultural component exists at the Kiwanis site, but that a multimethod, noninvasive geophysical approach to the questions posed by the site is suitable for answering such questions.

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