Analyzing and Presenting Resistivity Data from Emerald Mound Archeology Site in Attempt to Discover a Mississippian Trail

By

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ABSTRACT

The ancient city of Cahokia, located in southwest Illinois, was the largest Native American community north of modern-day Mexico and was best known for the large, mound like structures they built. Emerald Mound is considered to be a part of this ancient Mississippian culture and is located to the east of Cahokia. In a 1940 aerial image of Emerald Mound, there are two linear, parallel features resembling paths or roads that extend southeast from the mounds. These features cut across two modern roads and multiple farm fields but are no longer visible in today's aerial images or orthophotographs, likely due to modern agricultural modifications of the landscape. Understanding the travel techniques of these ancient civilizations can help us further understand their culture. However, visual analysis alone is insufficient to establish whether these features were indeed produced by human travel. In addition, other undiscovered roads may exist beneath today's fields. In this study, we tested electrical resistivity to see whether the method can detect these now-hidden features. Years of travel on a path would compress the soil beneath the theorized path and in an attempt to measure this, 10 resistivity lines were constructed perpendicular to the linear features. We measured resistivity at multiple depths (from 0.26 to 2.14 meters below the surface) along the 10 transects. Each profile was about 150 meters long and spaced approximately 100 meters apart. Most resistivity profiles showed higher resistivity in two regions: 40-50m and 110-120m from the south end, corresponding approximately to the location of the linear features. This pattern was consistent through multiple different profiles and depths, but was not detected in all profiles or depths. Despite limitations due to the signal:noise ratio in the data, the relative continuity of high resistivity values suggests that the linear feature was likely produced by this ancient civilization and is not a by-product of modern agriculture.

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INTRODUCTION

The presence and location of an ancient path can help one understand the culture that built and used it (Trombold, 1991; Rowland, 2008). Unfortunately, due to modern agricultural practices and urbanization, most ancient paths are no longer visible on the surface. Martino et al. (2006) used resistivity to determine the location of an ancient building for excavation, where only one wall was still visible, which is similar to locating a sub-surface road.

Electrical resistivity has the ability to locate sub-surface features because different substances have different resistivity values. Resistivity of a material describes how resistant that substance is to electricity passing through it. Compaction of the soil is one of many properties that play a role in resistivity. The compaction can be measured mainly due to the presence of pore space in the soil. Where there is more pore space, the resistivity is lower because electricity flows more easily through fluids than the solids of the soil. A more compact soil will have less pore space, and thus higher resistivity.

The presence and composition of fluids also affect resistivity data. Salt water has lower resistivity than fresh water or air. This difference is shown in a couple of studies, one by Mawer et al. (2011), who used electrical resistivity to measure the surface recharge of an aquifer and could differentiate resistivity values of different fluids in the pores. Also, in a study by Amidu and Dunbar (2008), reservoir salinity was measured in a lake in Texas by the difference in resistivity of the fluids. In a 2012 study by Ismail and Anderson, electrical resistivity measurements were used in Missouri to measure sub-surface karst cavities to determine the presence of sinkholes. As resistivity is quite difficult to understand, Riss et al. (2011) give a methodology for interpreting electrical resistivity into 2D models. Also, in a 2012 study by Brinon et al., a method for quantifying resistivity data is presented in using known archeological features to test their theory. The data experienced a change in resistance values when crossing the archeological feature, suggesting that resistivity measurements have the ability to measure shallow sub-surface features.

Since previous studies have concluded that resistivity has the ability to measure sub-surface features, it is proposed as a tool in this study to measure and locate the buried paths. If these paths are located, the direction and location can be used in further analyzing the culture that produced it. Resistivity is not commonly used in locating ancient paths but has been used for a range of other sub-surface purposes like locating aquifers, the water table, cavities, or other buried and submerged features mentioned above, and would be similar to the sub-surface mapping work of Brinon et al. (2012).

Geographic and Geologic Setting

The Cahokia settlement is located in southern Illinois, a few miles west of Collinsville, near the Mississippi River. Emerald Mound is located about 24 km to the east of Cahokia, in north eastern St. Clair County, northeast of Lebanon. Emerald Mound was constructed between AD 1050 and 1250 by the Mississippian culture and was an outlier of Cahokia, the largest Native American civilization north of present day Mexico (Koldehoff et al., 1993; Pauketat, 2004). The Emerald Mound site consists of one large mound as well as several smaller mounds slightly to the south, with the linear features to the southeast, pointing directly at the largest mound. The dual path feature is similar to other paths produced by ancient North American cultures (Sofaer, 2008). The mounds are different from the Cahokia Mounds because they were built on the uplands of the Illinois Episode till plain of southwestern Illinois on a Quaternary-aged glacial ridge, and not in the Mississippi River basin. A glacier leaves a ridge as debris is deposited along the sides of a glacier. These are usually composed of very heterogeneous glacial till due to the sorting properties of glaciers.

The Illinois Episode glaciation resulted in a very flat landscape and generally was not a moraine-building event. The ridges this event produced were usually segmented and poorly developed resulting in indistinct moraines similar to the one Emerald Mound is located atop (Ehlers and Gibbard, 2004). Above the till lays a thin layer of Peoria Loess. Loess is a fine-grained material, dominated mostly of silt-sized particles, that has been deposited to the area by wind (Wallace, 1978). This is a relatively thin portion of the soil horizon as bedrock is approximately 15 to 20m deep (Wallace, 1978).

The average annual rainfall is around 96cm, usually with less than 15cm of snow, most of which falls in the growing season. This rate also varies greatly from year to year, resulting in an unpredictable amount of water entered into the system each year. The mean temperature is approximately 60 degrees Fahrenheit (Russell, 1963). With the presence of the seasons, winter is much colder than summer, which allows for freezing and thawing of the soil. This factor can greatly affect the water table of the area, which is approximately between 4 and 7 meters from the surface, as well as the density of the soil (Russell, 1963).

The ridge lies about 10 m above the nearby landscape but the most noticeable elevation change occurs while approaching the man-made mounds. The largest mound stands at about 6 m tall and is located under a present day farm house (Larson et al., Unpublished). The soil composition ranges from silty toward the bottom of the mound, growing sandier while ascending in elevation. The linear features in question run to the southeast away from the mound. These features, in the 1940's aerial image, cross three different farm fields and across two separate roads, but are no longer visible in modern orthoimages.

Methods

Data Collection

During the summer of 2012, Tim Larson and I traveled to the Emerald Mound location to observe and measure the linear features present in the 1940s aerial image. While there, we laid ten resistivity transects along the features in order to measure the compaction of the soil. We used the aerial images to find coordinates of the locations to lay the transects. The actual locations were recorded using a hand held GPS unit with a position accuracy of 5 meters. Once located, the ten high-resolution shallow dipole-dipole earth resistivity transects were laid. These transects were spaced approximately 100 m apart and were 150 to 160 m long, perpendicular to the features (Fig. 1). The transects consisted of a series of rod shaped electrodes that were placed in a one meter array, and pushed approximately 15 cm directly into the soil. An ABEM Terrameter 4000 in a dipole-dipole electrode configuration was used to release and collect the current data. Currents ranging from 50-100 mA were released from one electrode and measured by the rest in the series. The amount received by the other electrodes was what produced the resistivity values. This technique allowed for the terrameter to collect measurements every 1.5 m and up to 2 m deep. The data was then transferred and stored in the device in ohms per meter. The measurement of ohms per meter is a measure of the amount of electricity passing through a distance. Features with high resistivity have little current passing through the material; in contrast, features with low resistivity allow more current per unit of length.

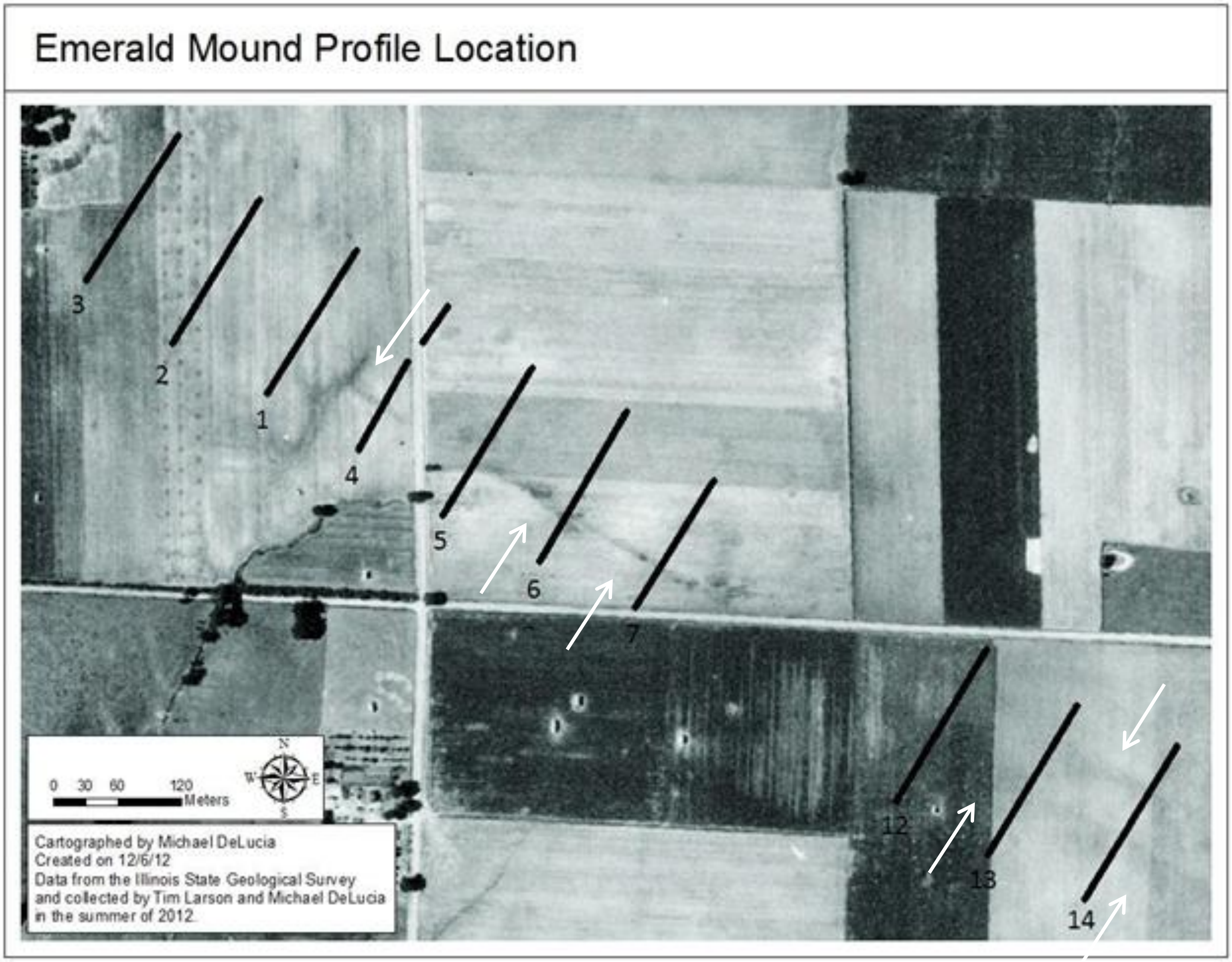

Figure 1: The locations of each transect and the number that correlates with them. The linear features are pointed out by the white arrows.

<u>Data Analysis</u>

After the ten transects were measured, the data were then transferred to a spreadsheet with the recorded resistivity data, depth of measurement, and the coordinates of the measurement location. Resistivity data was quite variable, so a 5-point running mean was employed to better visualize the patterns at the transect scale. The spreadsheet was then added to a Geographic Information System, ArcMap 10.1 (GIS). The x and y coordinates of the spreadsheet were used to place the individual resistivity points in GIS. Each point was given the value that corresponded to the running mean of 5 resistivity measurements. Each transect included data at six different depths (0.26m, 0.6m, 0.94m, 1.28m, 1.79m, and 2.14m), which were all mapped separately in an attempt to add another dimension to the resistivity of the soil. The 1940s aerial image was georeferenced in GIS using the 2004 orthophoto. A digital elevation model (DEM) was acquired from the Illinois State Geological Survey's data library. Surface contours were produced from the DEM in order to gain a better idea of the elevation of the area.

Results

After being transferred to an Excel spreadsheet, the data were loaded into GIS according to their GPS location with the resistivity accounting for the value. The scales of the resistivity are condensed into groups of similar values in the maps for more comprehensive analysis. The colors in the scales on any single map may correlate with different values and are intended to be compared to internally and only as patterns to the other maps. Know that in comparing to other depths, the pattern should be compared more than the colors representing raw values of the data. The spreadsheet of true resistivity data for all measured transects and their locations are in Appendix A.

After GIS entry, locations near the linear features were then graphed by their resistivity values to better visualize the trends. The resistivity is in ohm per meter and averages at 19.11 ohm per m, but can get as high as 100 ohm per m in more compacted areas and locations that are less saturated. As seen in all images in figure 2, there is a high amount of variability throughout each transect and at different depths. The further up the glacial ridge that the transects are, they show an increase in resistivity values.

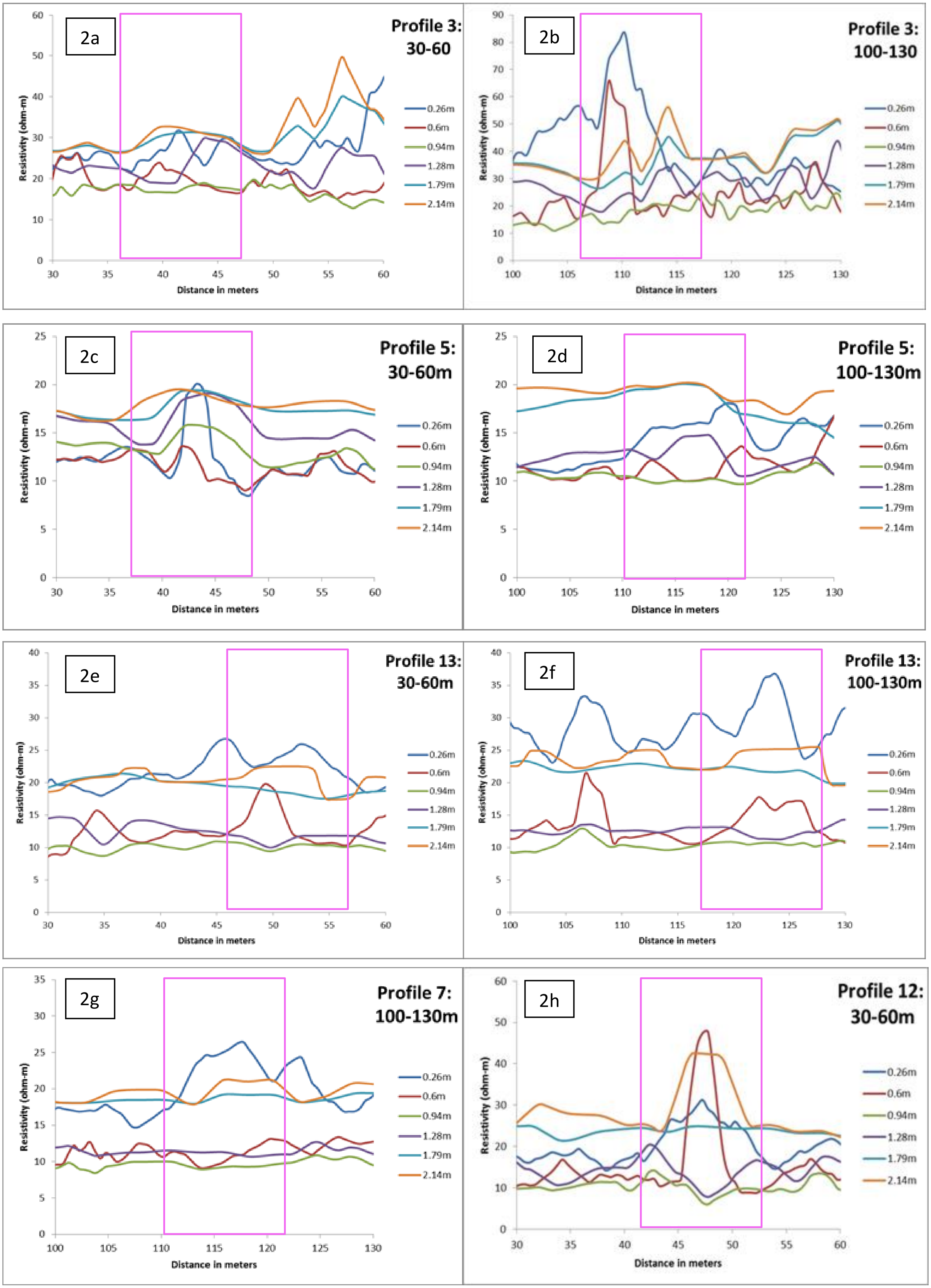

Figure 2 (a-h): Running mean of 5 of the resistivity in ohm-m against the distance in meters of transects 3, 5, 13, 7, and 12, from 30-60 and 100-130 meters respectfully. The pink box represents the location of the theorized linear feature being investigated.

Other patterns include increases in resistivity at the locations in the transects where the linear features are crossed. These patterns do not exist in all transects, across the six depths, but there is an overall pattern of increased resistivity correlating to the same distance down the transects. As seen in figure 2c, there is an anomaly of increased resistivity that lasts for about 10 m down the transect. The anomaly begins about 36 m down the transect and ends at about 46 m. Throughout the data, there is a common trend of anomalies that are about 10 m long and located at 35-45 m and 110-120 m down the transects. There is a slight variation in these distances throughout the transects as the GPS unit used was accurate to about five meters. There is an exception to this pattern located in line 13. That line was started 10 m further south moving the existing anomalies 10 m up the transect which is evident in figure 2e and f.

The higher resistivity patters are especially visible in transects 3, 5, 12, and 13 and are not evident transects 6 and 7, which display low resistivity in areas corresponding to the southernmost linear feature. But, as seen in figure 2g, the northern linear feature is represented by an area of high resistivity in transects 6 and 7. The anomalies do not represent the areas of highest resistivity, but they do seem to follow similar trends in multiple different depths that, for about ten meters, the resistivity is higher than the neighboring data right before and right after. This is evident across almost all transects.

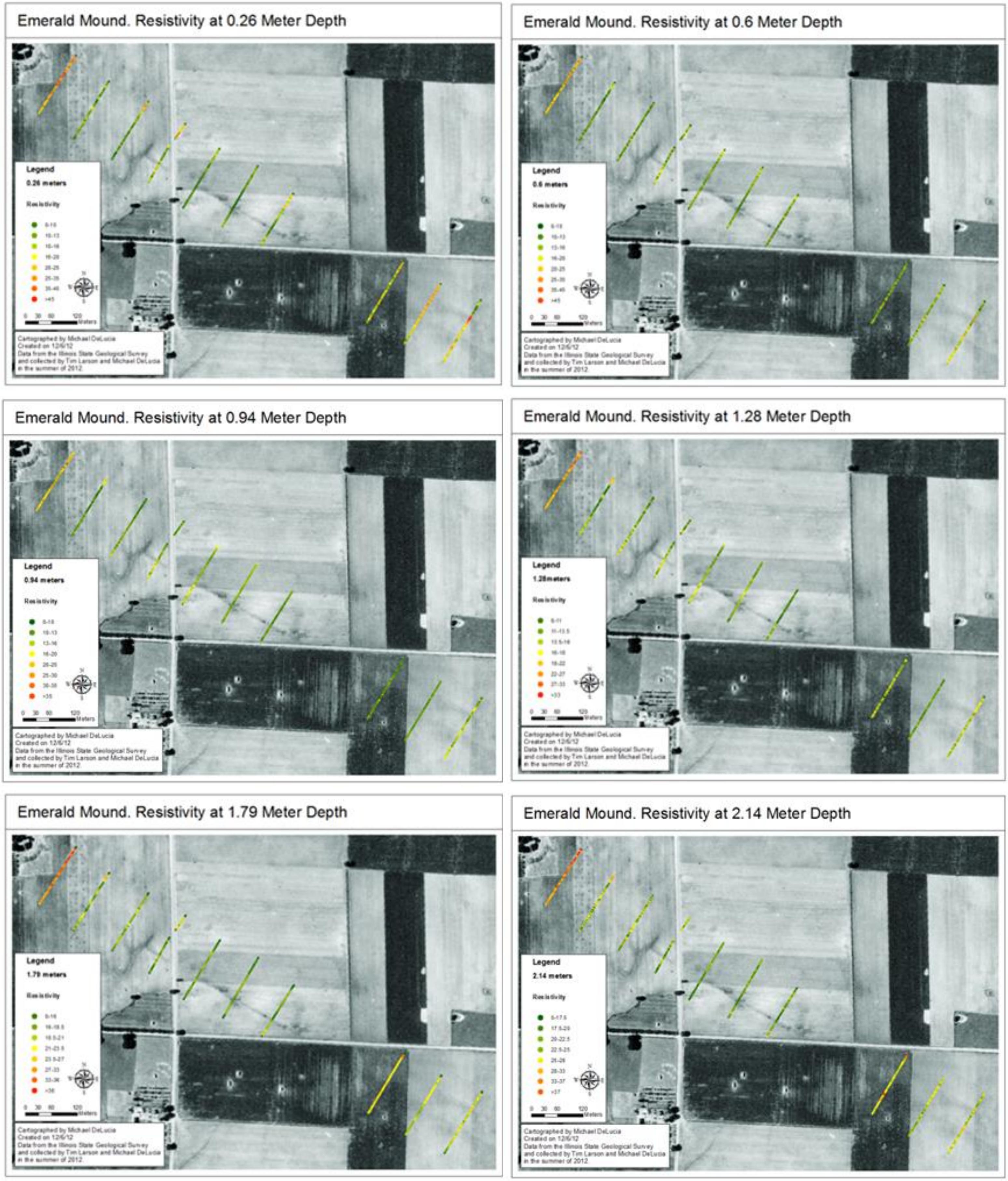

Figure 3: The six depths; 0.26, 0.6, 0.94, 1.28, 1.79, and 2.14 meters, mapped using the resistivity values with a running mean of 5. Scales do not directly correlate between the maps. Red resembles locations of high resistivity data whereas green represents low resistivity.

Discussion

Our analysis of the data shows localized patches of high resistivity that correlates with the location of the linear features in question. This finding shows that resistivity can be used in locating ancient buried roads or other buried archeological features. Resistivity values reach up to 50 ohm-m and beyond at the locations that correspond with the features, where the average resistivity of the transects is around 19.11 ohm-m. In some locations, according to Figure 4, resistivity spikes above 1.5 times that of the localized average.

The resistivity data collected at Emerald Mound was very erratic which is why a running mean of five has been used for results and analysis. The data visually correlates with the ancient road. The resistivity data peaks at two locations in each transect, at virtually all depths (Figures 2-3). These resistivity peaks are located between about 40 and 50 m for the southern feature, and between 110 and 120 m for the more northern feature, which aligns them with the ancient paths. The southern feature is more defined in the resistivity data as well as on the 1940's aerial photo, so it will be the primary focus of the discussion.

There seems to be a local peak that correlates with the two linear features. The scales for resistivity on the maps are not consistent, so the maps are intended to be compared individually or as a pattern of local resistivity highs. The pattern of local resistivity peaks is most defined in the southern most transects, while the transects closer toward the mound are more erratic and the patterns are less evident. There is a location where the data shows lower resistivity data where the anticipated road is theorized to be. Between the two roads (lines 5, 6, and 7), the data does not follow the pattern of resistivity peaks for the southern feature, but rather seems to represent the opposite. This anomaly could be due to the physical terrain of the area. While taking the measurements, we noticed a slim but relatively long (about 80 meters) topographic depression in the ground that almost followed the linear features in question. This depression could be the reason for the data in lines 5, 6, and 7 to not follow the pattern correlation with the linear features due to more saturated soil or a variety of other reasons.

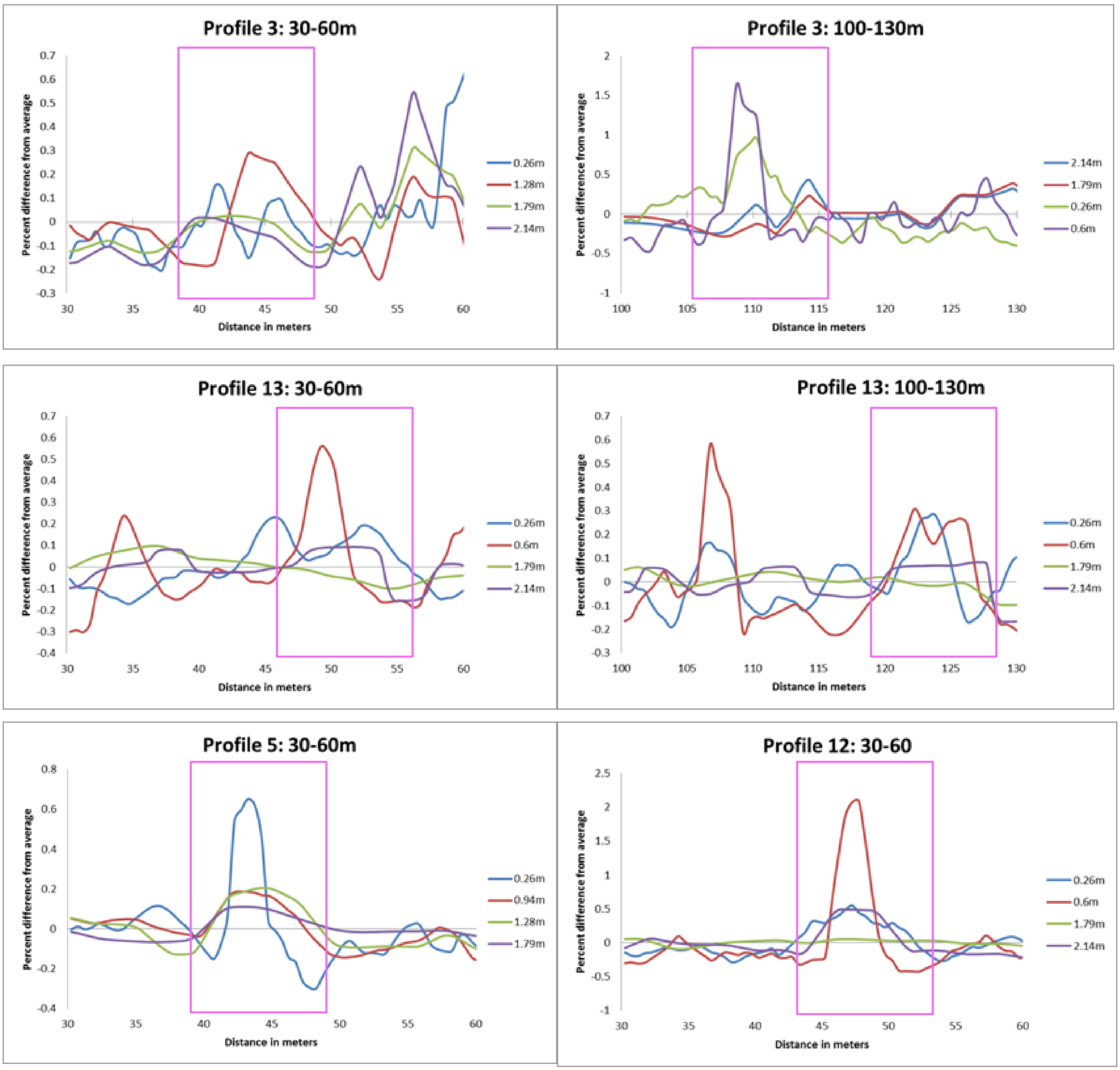

Figure 4: Percent of difference from the average with a running mean of 5, of transects 3, 5, 12, and 13 with their distances from 30-60 and 100-130 meters respectfully. Pink boxes are used to represent the theorized location of the features.

The data, still noisy, was graphed on a smaller scale to show the theorized location of the road and the local conditions surrounding it. In each of the transects, the hypothesized road locations did not necessarily have the highest resistivity values. There are higher values at other locations that may be due to change in soil type, depth, water saturation, or other factors. Although not representing the highest resistivity, there is a pattern of local highs between about 40-50 and 110-120 meters. This pattern is not consistent at every depth measured, but occurs too frequently to be considered a coincidence. The linear features may not match exactly in distance along the transects due to the 5 meter accuracy of the hand held GPS unit used in locating the transects.

From the localized graphs produced above, a standard deviation percent graph was produced in order to quantify the difference (from the average) of the resistivity values of the theorized road (Fig. 4). This was done by taking the resistivity value of a point, subtracting the localized average, then dividing that number by the average. The resistivity values are up to two times higher than the average in some locations where the road may be (Fig. 4, lines 3 and 12). In most cases, the resistivity spikes are around 0.2-0.6 times higher than average.

Representing the resistivity data into these standard deviation graphs really show the amount of uncertainty and noise involved in the measurements. There seems to still be a pattern consistent with the theorized linear features, but is not consistent in all lines or throughout all depths. The transect graphs made above (Fig. 2 and 4) were chosen due to their strength of correlation to the pattern. They are not the only transects that represent the theorized road, as there are more, but there are also resistivity transects that hold less strength in supporting the location of the hypothesized road. Some seem to represent this pattern quite well where others, like transect 3 from 30-60 (Fig. 2 and 4), are relatively inconsistent.

Conclusion

A pattern of localized high relative resistivity correlates with the locations of the linear features for the majority of the transects and depths, but does not appear consistently throughout all. Many factors, other than compaction of the soil, affect resistivity measurements which could be the reason for the erratic measurements recorded. Nevertheless, the continuity of this pattern occurs far too often to be considered an anomaly of the heterogeneous soil. This study concludes that resistivity measurements can determine the location of buried archeological features and that this feature is man-made and predates historical European settlement.

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