

# Using Ground Conductivity as a Geophysical Survey Technique to Locate Potential Archaeological Sites in the Bad Axe River Valley of Western Wisconsin

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## ABSTRACT

The Cade Archaeological District located in the drainage basin of the North Fork of the Bad Axe River of Western Wisconsin has 17 recorded prehistoric sites. These sites include both habitation sites and effigy mounds. The effigies are located on landforms such as steep hillsides, toe slopes, and valley bottoms. The goal of this research was to try to locate any significant archaeological formations by using an Electromagnetic (EM) ground conductivity meter. Without implementing other geophysical survey techniques, or excavating areas of interest, it is difficult to absolutely identify culturally emplaced material. While it is uncertain as to whether or not our results identify any culturally emplaced materials, there are significant conclusions about the geomorphology of the area that might be interpreted from our data. The nature of EM ground conductivity allows for much speculation in terms of the resulting data.

## INTRODUCTION

### *Background*

The Bad Axe River lies in Vernon County, Wisconsin and drains approximately 190 square miles of interior Driftless Area valleys (Figure 1). The river itself is divided into two distinct branches; the North Fork and the South Fork, draining 81 square miles and 85 square miles respectively. The area has been inhabited since Archaic times, although most of the preserved archaeological sites are from the Woodland and Oneota periods. Our search for new archaeological sites centered on the North Fork of the Bad Axe, specifically the Cade Archaeological District. The Cade Archaeological District, a National Register property, has 17 recorded prehistoric sites consisting of both habitation sites and effigy mounds.



**Figure 1.** The North Fork of the Bad Axe River Valley and surrounding bluffs typical of interior Driftless Area topography. The survey site lies between the two bluffs in the middle ground.

Mounds in the area of the Cade Archaeological District most likely date to the Late Woodland Effigy Mound culture present in southwestern Wisconsin ca. A.D. 750-1050 (Boszhardt and Goetz 2000). These effigy builders represent the Eastman phase, and sites of this phase are common in the Prairie Du Chien locality, but extend north to the Bad Axe valley. The primary function of these effigy mounds, numerous and widespread along both forks of the Bad Axe, probably was to mark social and/or economic territory (Theler and Boszhardt 2000). Our research focused on a reported bird-shaped effigy mound located to the west of the Cade farm (Figures 2 and 3). For our survey we chose to use ground conductivity as a means of remote sensing to study the area in question.

### *EM Theory*

By using electromagnetic (EM) ground conductivity, we were able to retrieve information about the sub-aerial properties of the survey area. EM conductivity (explained further in Beauchaine, 2004) relies on the conductive properties of the soil or rock structure beneath the surface to provide data. For our survey we used a GF Instruments CM-031. The meter itself is composed of a transmitter coil and a receiver coil both set up in a vertical orientation separated by three meters in the case of the CM-031 (GF Instruments 2001). A signal is emitted from the transmitter end of the unit which produces eddy currents in the ground material. These eddy currents in turn produce a secondary electromagnetic field which is measured by the receiver coil of the meter. In essence, the difference in the electromagnetic wavelength is proportional to the conductivity of the ground material.

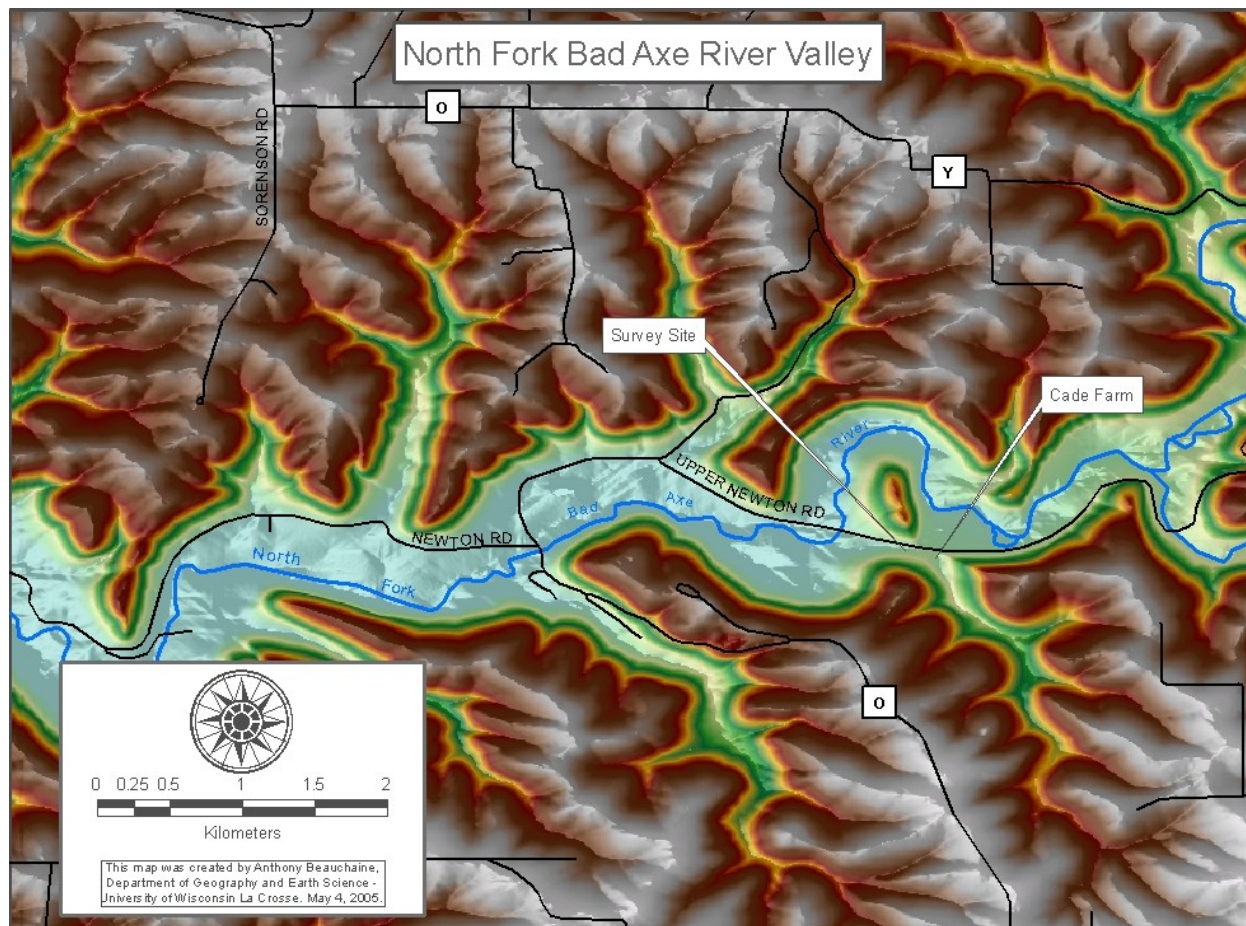
There are several factors that influence the conductivity of the ground material. The most important of these factors is the amount of moisture contained within the soil. This can greatly affect the data as more moisture inherently results in higher conductivity. Another important factor is the porosity of the ground material. This directly influences conductivity and indirectly affects moisture content. Other factors that have an effect on conductivity include the clay/colloid content of the soil, concentration of dissolved electrolytes in solution, and the temperature and phase state of the moisture within a soil (Mc Neill 1980).



**Figure 2.** Photo mosaic of the survey site looking south.

The CM-031 provides two data measurements; the conductivity measured in millisiemens/meter and inphase (magnetic susceptibility), a unit-less measure. By analyzing these data, we can infer something about the ground material and whether or not it could potentially be culturally emplaced. Areas of high and low conductivity provide good indications of culturally emplaced soils. However, culturally emplaced soils may have high or low values depending on other factors. Dalan and Bevan (2002) refer to two different sites (The Deer Creek site in northern Oklahoma and the Cahokia Mounds State Historic Site in southwestern Illinois) where known, but leveled mounds, produced anomalies. However, the Deer Creek mounds indicated high conductivity readings, whereas the Cahokia mounds were distinguished by conductivity lows.

The inphase component of the measurements can be useful for detecting areas of high conductivity due to the sensitivity of the inphase measurement. Since the CM-031 operates at a frequency of 9.766 kHz, the inphase component is practically independent of the conductivity (quadrature) component. At frequencies below 10 kHz areas of low conductivity provide a similar shape and response in both inphase and conductivity. On the other hand, features of high conductivity react much more sharply in the inphase component (Herz and Garrison 1998). This interpretation of the inphase component can be useful for determining culturally emplaced soils or artifacts.



**Figure 3.** Survey site location in the North Fork Bad Axe River Valley.

## METHODS

For our survey we decided on a 60-meter by 60-meter grid set up with its profiles running in an east-west orientation. Surveying was done by the same individual in order to maintain uniform measurements. Given the separation of the transmitter and the receiver coils (3.74 m), it was decided that the most reasonable spacing distance for measurement points was three meters. This grid pattern spacing allowed some overlap, but avoided redundancy. The survey was conducted in two “halves” by walking only to the 30 meter point on each profile and back for the width of the survey area, and then continuing on to the second half, from the 33 meter point to the 60 meter point on the profiles. This created a west “half” and an east “half”. The measurements were continuous, but provided interesting results for the inphase component, which will be discussed in the results section of this paper.

After conducting the survey, a soil pit was excavated to further determine the context of our data. The soil pit was located on the eastern edge of the survey area and was excavated to a depth of approximately one meter (Figure 4). Once the data was gathered, it was uploaded to a computer and analyzed using Surfer software among other programs. Through a series of steps involving transformations of data, data processing, and data cleaning, contour maps were created which showed the direct measurements of the CM-031. These contour maps, showing lines of equal values, were helpful in further analysis of the data. The gridding method used for interpolating data points is known as the “radial basis function” which is quite flexible and compares to the Kriging method of gridding in that it generates the best overall interpretations of most data sets according to the Surfer program’s help files (2004).



**Figure 4.** Soil pit on the eastern margin of the grid.

## RESULTS

While the intended goal of our survey was to locate archaeological sites or artifacts, we found that our results did not provide sufficient evidence of any culturally emplaced material. The results of our survey were relatively uniform, with some variations in the conductivity and inphase that can be explained through the geomorphology of the area. With the exception of an area of very high conductivity and magnetic susceptibility just south of Upper Newton Road, there were no anomalies that would immediately suggest any culturally emplaced ground material.

The data gathered from the conductivity measurements produce values ranging between 7 and 15 mS/m (Figure 5). Low conductivity values were located in the central portion of the survey area along with the east and southeast areas of the survey. One obvious area of high conductivity values is located in the southwest corner of our survey area. This area produced the highest values of conductivity that seem to be decreasing in values uniformly by distance outward from this area. An interesting anomaly is found near the northern margin of the survey grid, just south of Upper Newton Road. This linear feature can be found on the grid along profile 57 between points 6 and 48. On the northern margin of the survey itself, along profile 60, there is also an area of extremely low conductivity values.

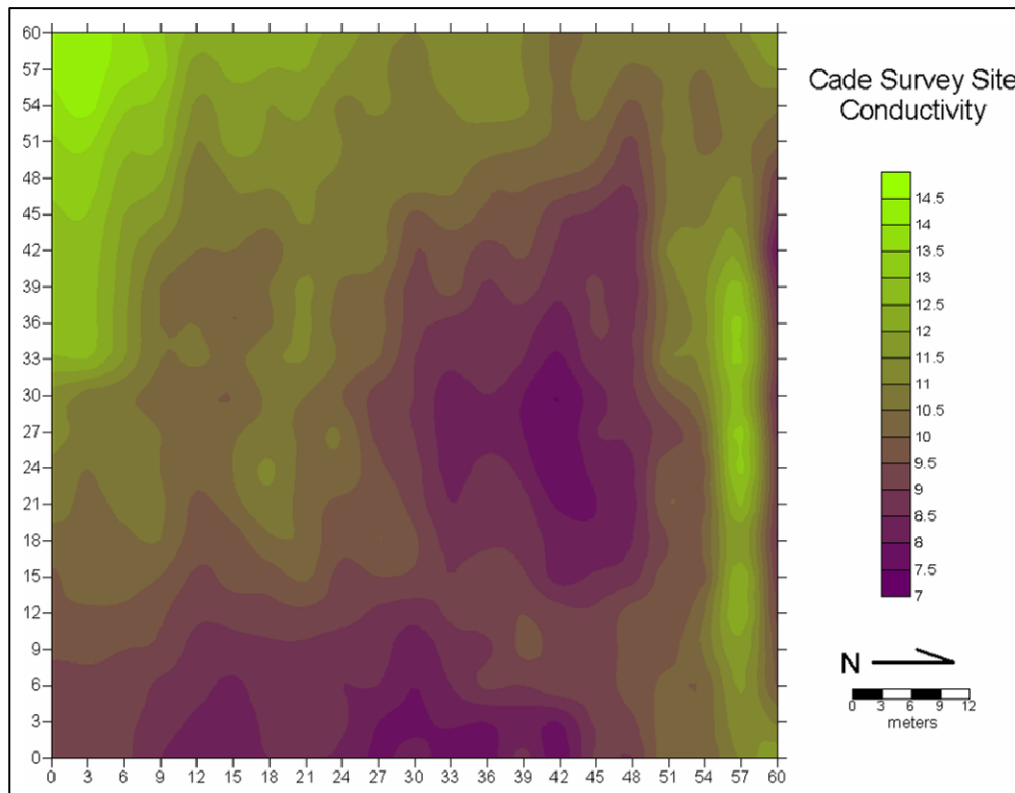
The inphase component of the measurements provided a very uniform decrease in values throughout the duration of the survey (Figure 6). Values measured ranged between 1120 and 1145 relative units. High values originate in the southeast section of the grid and decrease to the northeast. These values continue to decrease to the northwest, and then to the southwest. This pattern has a very uniform gradation which will be explained in the discussion section of this paper. Along with the conductivity results, the inphase component measured the same linear anomaly near the northern margin of the survey grid. Extreme highs were recorded in the same area along profile 57, and similar low values were obtained on the northern margin along profile 60.

## DISCUSSION

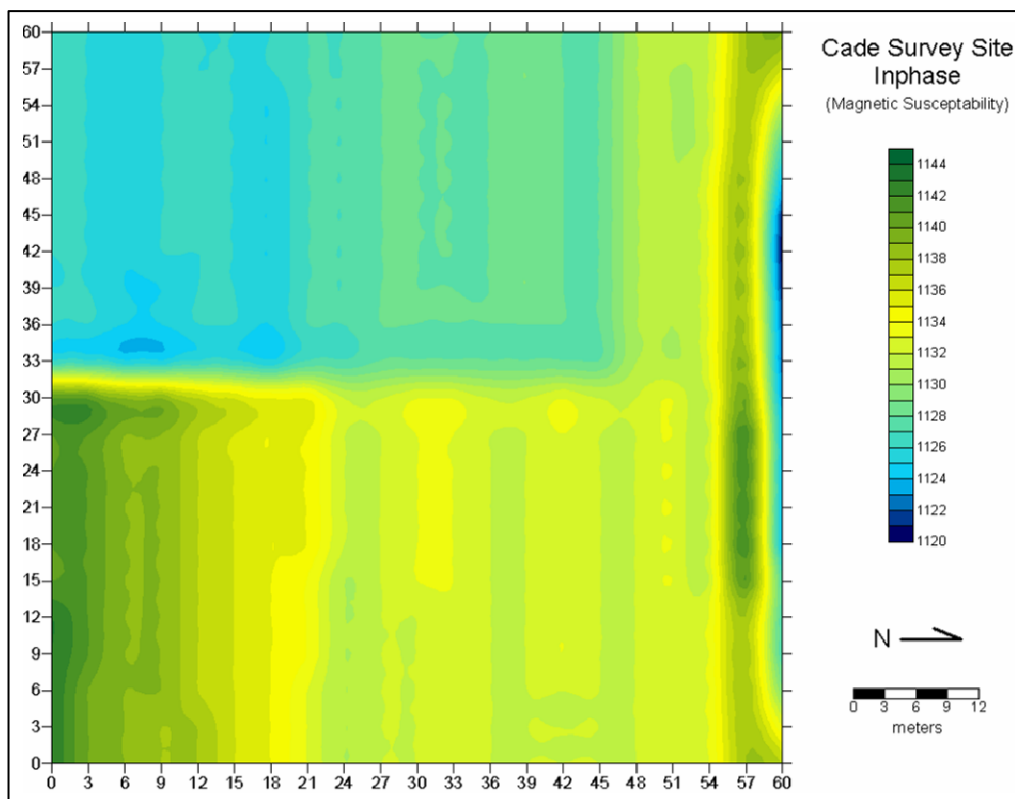
The first thing that should be taken into account for the survey is the topography of the land on which the survey was located. Most of our results correspond to physical features and properties of those features. While there was not any good evidence of culturally emplaced materials, we were able to learn some things about the geomorphology of the area by analyzing the results of our survey.

The conductivity results can be interpreted as a product of the ground material, which has been deposited from numerous debris flow and alluvial fan formation processes. The areas of low conductivity can most likely be attributed to debris flows of large rocks that have washed down the tributary valley to the southeast of the survey area and the Cade farm. These large cobbles and boulders provide areas of high resistance to electrical current, and therefore, provide lower conductivity. An example of this debris flow can be seen in Figure 4. Underlying a distinct organic Ap soil horizon there were significant stratigraphic layers of sand along with gravel, cobbles, and at a depth of one meter, very large boulders. These layers of cobbles and boulders are most likely the result of mass wasting events/debris flows from the valley to the southeast.

Areas of high conductivity in the southwest corner of the survey grid are most likely the result of a small alluvial fan formation at the base of the southern bluff. Such an alluvial fan formation contains much smaller particles than would a debris flow. This small alluvial fan is comprised of much smaller silt and clay particles that allow for the retention of moisture within the soil. This greater ability to retain moisture results in a greater capacity for conductance. For this reason we believe that the high conductivity values are the result of the ground material being comprised of sand, silt and clay-sized particles.



**Figure 5.** Lower conductivity values indicate presence of debris flow deposits. Alluvial fan deposits appear as high conductivity values in upper left (southwest) corner of survey area.



**Figure 6.** “Electronic drift” phenomenon is apparent due to temperature variations.

The linear anomaly along profile 57 would in most cases be an area of interest, however in this case this anomaly is most likely the result of a buried power or telephone cable. Other explanations might be the result of the construction of Upper Newton Road, although this is merely speculation. Further investigations would be helpful in determining what this anomaly is. In this case, conductivity measurements did not provide any substantial evidence of culturally emplaced ground materials other than the historic buried power/telephone lines.

The inphase data offered little insight into whether or not there were any prehistoric culturally emplaced ground materials. The first thing that needs to be taken into account when analyzing the inphase data is the phenomenon known as electronic drift. The EM conductivity meter can be affected by electronic drift due to diurnal temperature variation if the meter is not insulated properly (Clay 2001). We believe that an increase in the temperature throughout the duration of our survey resulted in successively lower values for magnetic susceptibility. This explains the apparent declining “ramp” of values, with the highest values in the southeast corner where the survey was initiated, and the lowest values in the southwest corner where the survey was finished.

The inphase also detects the same linear anomaly as the conductivity along profile 57. The inphase measurement, however, does detect the anomaly for the entire length of the profile, whereas the conductivity measurement does not. This is most likely due to the higher sensitivity of the inphase measurement in regards to areas of high conductivity. This supports our thinking that we are seeing buried power line of some sort that is highly conductive. Other than telling us something about temperature drift, the inphase component in this case does not tell us much about any culturally emplaced materials.

## SUMMARY

The survey conducted in the North Fork of the Bad Axe River Valley of western Wisconsin was intended to be “test application” of EM ground conductivity using the CM-031. With the number of archaeological sites in the Cade Archaeological District, it seemed that the survey would provide excellent information on the area, regardless of whether or not any culturally emplaced materials were present. While this survey did not offer definitive evidence of any culturally emplaced material, other geophysical survey techniques should be utilized in conjunction with EM conductivity in order to be certain. The methods used in this survey were basic and primary methods which were intended to provide a better understanding of the Cade Archaeological District. In this regards, the presence and spatial extent of significant debris flow deposits were clearly identified based on EM ground conductivity measurements, thus adding to an overall understanding of landscape formation processes.

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