

Geophysical Prospection in the Cade Archaeological District of Vernon County, Wisconsin

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ABSTRACT

This thesis undertakes an intensive geophysical survey in order to test the archaeological applicability of the geophysical equipment available at the University of Wisconsin-La Crosse while attempting to document potential archaeological features that may aid in future excavations. It also employs a new method of survey in the Cade Archaeological District that may contribute to the understanding of the spatial distribution and expansion of the Late Woodland Cultural Tradition. The Cade Archaeological District, located along the North Fork of the Bad Axe River Valley in Vernon County, Wisconsin, has more than fifteen documented archaeological sites. The major archaeological research that is being conducted in the area regards the expansion of the Late Woodland Tradition into year round settlements in the valley. Although the Bad Axe River Valley is rich in archaeological history, determining the best place to begin excavating can be difficult as many sites lie below post-settlement alluvium. Geophysical techniques can aid in locating buried archaeological features by detecting anomalous soil signatures among the normal soil background.

INTRODUCTION

There are many areas in the North Fork region of the Bad Axe River that have the potential of bearing buried features. Numerous prehistoric occupation sites have been documented in the Bad Axe River Valley with sixteen located in the Cade Archaeological District. The major archaeological research that is being conducted in the area regards the expansion of the Late Woodland tradition into year round occupation of the valley (Theler and Boszhardt 2006).

Although geophysical research has proven to be beneficial to the archaeologist, it is not often employed in North American archaeological investigations. These methods, however, have broad applicability within all archaeological paradigms (Dalan 1995). This thesis undertakes a geophysical field survey in the Cade Archaeological District at the 2007 University of Wisconsin - La Crosse (UW-L) archaeological field school site.

The purpose of this field work was to demarcate possible cultural features that lie below post-settlement alluvium. If features were detected, it would aid the 2007 field school instructor in determining the best area to excavate. The excavations will further the understanding of the settlement patterns of the Late Woodland Tradition in the area. The geophysical survey will contribute to both the Departments of Geography/Earth science and Archaeology/Sociology at UW-L while fulfilling the following objectives:

- 1) To document geophysical anomalies that may indicate potential archaeological features.
- 2) To employ a new method of survey in the Cade Archaeological District that may contribute to the understanding of the spatial distribution and expansion of the Late Woodland Culture.
- 3) To use UW-L's geophysical equipment for an interdisciplinary purpose, while exploring how the equipment would work for archaeological purposes.

Archaeology is a field that must rely on a multi-disciplinary approach in order to identify and interpret archaeological context. Geophysics is one of these fields of study that has relatively recently been used to aid in the survey and identification of cultural resources. Geophysical survey methods can be beneficial to the archaeologist in a variety of ways. It can direct archaeologists to features of interest. This helps to save time and money during site explorations. The basic layout of the subsurface and the location of features can be mapped to aid in the management and planning of archaeological sites. The mapping of sites in this manner also allows for the research and analysis of settlement patterns (North American Database of Archaeological Geophysics 2006).

According to the University of Arkansas' Dr. Ken Kvamme (personal communication 2006), the goals of geophysics in archaeology are to detect, map, interpret, and explain subsurface conditions within an archaeological context. Data interpretation revolves around finding anomalies, or contrasts, within the "normal" soil background.

Anomalies can arise from biological, geological, pedological, and cultural causes. The task of the archaeogeophysicist is to sort out the cultural from the natural.

BRIEF HISTORY OF ARCHAEOLOGICAL GEOPHYSICS

Augustus Pitt Rivers wrote of his 1893-1895 excavation at Handley Down in Dorset, England. He describes the first time that a 'geophysical' method was employed for archaeological detection. The technique that was used is known as 'bosing.' This is where the flat end on the head of a pick is hammered on the ground in order to determine where an archaeological site is by the sound that is produced. Rivers wrote that "the sound produced by hammering on an excavated part is much deeper than on undisturbed surface." The use of this technique allowed Rivers and his team to discover a ditch that was not visible from the surface of the grass-grown downland (Clark 1990).

Fifty years later, Richard Atkinson became the pioneer in what can be considered modern archaeogeophysical survey. Atkinson learned of resistivity surveying from a civil engineering journal. The article that caught his interest described resistivity surveying done by Evershed and Vignoles for site exploration for dams. He thought that the same method might be useful for archaeological prospecting. In 1946, Atkinson hired Evershed and Vignoles to produce a skeleton survey of the Dorchester-on-Thames site using resistivity measurements from the Megger Earth Tester. Their method proved to be time-consuming, so Atkinson rented a Megger from them and devised his own survey method, which was better suited for an archaeological site (Clark 1990).

The Megger was powered with a hand cranked generator. This was the main technique used for resistivity surveys until the transistor was developed in the 1950s. The transistor allowed for circuits to be both complex and compact, while utilizing less power. John Martin and Anthony Clark collaborated in 1956 to produce a resistivity meter, called the Martin-Clark, specifically for archaeological purposes (Clark 1990).

Fired clay becomes weakly magnetic during a process called thermoremanent magnetization. This occurs as iron oxides at high temperatures are magnetized by the Earth's magnetic field as they cool (Clark 1990). The direction of the Earth's magnetic field has changed and will continue to change over time. This paleomagnetism allows for the dating of geological deposits. At the same time, magnetic north is drifting around geographic north. When a kiln or fire pit is heated above the Curie point, the iron particles are reset to point to the direction of magnetic north during the time that the pit or kiln was fired. Archaeomagnetic dating allows these features to be dated according to this polar drift (Michaels 2001).

After a lecture given by John Belshe discussing archaeomagnetic dating in 1957, Graham Webster inquired as to whether a magnetometer might be able to detect buried burnt clay at archeological sites. It was determined that this would be a suitable application for a magnetometer; so, a prototype was developed. The instrument was found to be sensitive to both kilns, as well as to soil-filled features such as ditches and pits (Clark 1990).

The successful use of resistivity and magnetometer surveys spawned research into other geophysical techniques that could be applicable to archaeology. These include the use of gradiometers, magnetic susceptibility meters, electromagnetic conductivity, and ground penetrating radar. Geophysical technologies continue to develop and become more efficient concomitant with the computer industry (Clark 1990).

COMPLEMENTARY TECHNOLOGIES

Geophysical technologies are complementary. Multiple technologies should be used during projects because field conditions are variable. The various technologies capture different geophysical qualities of the earth. Combining the data sets obtained from different instruments allows for a multifaceted view of the ground (Clay 2001).

Many times cost is the factor that determines which type of geophysical survey is conducted. Equipment is very expensive and it is rare to have access to a large selection. It is important, however, to try to budget for at least two different forms of geophysical equipment (Clay 2001).

The University of Wisconsin-La Crosse houses two forms of geophysical equipment in the Department of Geography and Earth Science. These are the Bartington MS2 magnetic susceptibility meter with the MS2C core scanning sensor and the MS2F probe, and the GISCO CM-031 electromagnetic conductivity meter (Dean Wilder, personal communication 2006).

MAGNETIC SUSCEPTIBILITY

All atoms react to magnetic fields; therefore, all materials have a magnetic susceptibility. Magnetic susceptibility is the degree to which a material is magnetized in response to an applied magnetic field. A magnetic susceptibility meter injects an alternating magnetic field into the ground and then measures the response (Clark 1990).

Magnetic susceptibility is useful to the archaeologist because of two factors. The first is that topsoil generally has a greater susceptibility than the underlying soil layers; and the second is that the susceptibility becomes even greater with human occupation. The magnetic properties of soil are mainly determined by the iron content in the parent material of the underlying bedrock. Iron compounds are relatively insoluble and tend to accumulate in topsoil. Therefore, the topsoil in a particular region will have its own unique characteristic measurement of magnetic susceptibility. This characteristic soil signature contrasts with any culturally modified soils that may be present. The limits of site boundaries, which may only exist in the topsoil, can be identified by comparing and contrasting measurements from within and outside of the site (Clark 1990).

The MS2 produced by Bartington Instruments is the standard instrument used for acquiring magnetic susceptibility measurements (Clark 1990). A variety of sensors are available for use with the MS2 in order to achieve different methods of data acquisition. UW-L currently owns the MS2C and MS2F sensors (Dean Wilder, personal communication 2006).

The MS2C sensor is for use within a laboratory. Soil core samples are taken in the field and then brought back to the lab for analysis. This method can be time consuming when conducting a large survey (Clark 1990).

The MS2F sensor is attached to a handle which connects to the oscillator electronics. The tip of the probe has a diameter of 1.5 centimeters. It was designed so that the tip would be small enough to be pushed through vegetation on relatively flat surfaces. If there is a prominent root mass, a small hole can be cored out of the ground and the sensor inserted into the hole for measurement taking. The F probe sensor is only sensitive to the magnetic susceptibility of the material with which it has immediate contact. With it, readings can be taken at shallow depths or vertically on exposed wall surfaces (Clark 1990).

Magnetic susceptibility may be best used in conjunction with another form of geophysical survey. For example, a ground conductivity survey may be employed in order to detect the location of a feature. Once this location has been determined, magnetic susceptibility measurements can pin-point the boundary of the feature (Dean Wilder, personal communication 2006).

ELECTROMAGNETIC CONDUCTIVITY

Earth conductivity meters measure the ability of below-surface material to conduct an electromagnetic signal (Clay 2001, Dalan 1995). It measures the ease of flow of a generated electrical current through a substance. Resistivity is another form of geophysical technology and is the reciprocal of conductivity. Resistivity measures the resistance that a material provides to a generated electrical current (Dalan 1995, De Vore and Heimmer 1995).

Electrical currents are conducted through the motion of ions in soil, rock, or sediments. These ions are contained in the moisture-filled pores between mineral grains. "Hence, resistivity and conductivity are dependent on porosity, permeability, water content, and water quality (Dalan 1995)."

Structural remains comprised of stone, brick, mortar, cement, and other construction materials tend to have lower conductivities than that of the surrounding soil. Earthen features such as filled pits and ditches, hearths, earth lodges, graves, and mounds can have either high or low conductivity depending on the surrounding soil matrix. If they retain moisture well or are surrounded by rocky sub-soil they will produce a high conductivity (Dalan 1995).

Conductivity meters can be operated by one person. They are also suitable for use in bushy terrain and can penetrate through dry, hard, and rocky conditions (Dalan 1995). Conductivity surveys allow large areas to be covered rapidly. When being used over a small grid size, for example 20m x 20m, it has the capacity to efficiently collect data at close intervals to produce high resolution output. Collecting high-density datasets is not efficient or necessary however, during large, exploratory surveys with the conductivity meter (Clay 2001).

The CM-031 ground conductivity meter has an effective penetration depth of up to six meters. Smaller features at deeper depths will not be as easily detected as larger features at the same depth. A feature can be detected to a maximum depth that is approximately equal to its size (Dalan 1995).

The resolution of the output data can be adjusted by operating the conductivity meter in either the vertical or the horizontal dipole modes. The normal operating mode, or vertical dipole mode, is when the transmitter and plane of receiver coils are aligned horizontally. This method gives maximum resolution at a depth of six meters (De Vore and Heimmer 1995, Dalan 1995).

The instrument can also be turned on its side with the plane of receiver coils in a vertical position. The peak resolution when the conductivity meter is being used in the horizontal dipole mode is at three meters below the surface. This allows for features that are closer to the surface to come through with a higher resolution than those that are located deeper (Dalan 1995, De Vore and Heimmer 1995).

ARCHAEOLOGICAL APPLICATIONS OF GEOPHYSICAL SURVEY

Geophysical survey can direct archaeologists to features of interest. The amount of time and money spent during site explorations may be reduced when using geophysics. But, perhaps most importantly, these methods are non-destructive and maintain the integrity of the site for future generations. They can also provide a means for investigating culturally sensitive burial, sacred, or ceremonial sites (North American Database of Archaeological Geophysics 2006).

Cahokia Mounds State Historic Site in Collinsville, Illinois is an example of a site that has benefited from the non-destructive nature of geophysical surveys. Cahokia was a large Mississippian center that flourished from around AD 800 - 1400. The site included a large central plaza surrounded by wooden palisades and earthen mounds used for fortification. More research is needed to better understand the complexity of the site. However, urban sprawl, agricultural practices, past excavations, and construction of the park have already disturbed or destroyed a large portion of the site. Research must continue, however, if it is done through multiple excavations, the integrity of the site will be compromised. The use of geophysical techniques in future investigations may offer a solution to this problem (Dalan 1989, 1991).

Rinita Dalan of Minnesota State University Moorhead has completed geophysical surveys at Cahokia. The primary focus of her 1987 – 1989 surveys were to assess the use of electromagnetic remote sensing methods for detecting archaeological features at Cahokia. Specifically, Dalan's work regarded the Central Palisade. The geophysical data that was acquired was used to determine where to center excavation units along the route of the palisade. The areas that were determined to be most suitable for excavation were areas that seemed to have intact and relatively undisturbed remains (Dalan 1989).

Dalan used a variety of electromagnetic instruments manufactured by Geonics. The instrument that Dalan used that is of interest for the scope of this paper is the EM31 (Dalan 1989). The basic mechanics and parameters of this instrument mirror that of the CM-031, which was used in the geophysical survey at the Cade site.

Prior to Dalan's work, only 27 meters of the southern course of the palisade were documented. The results of her survey established an estimated 200 meters for the length of the southern course. The Central Palisade as a whole was found to extend for approximately 2950 meters; whereas before the geophysical survey, only 227 meters of the entire Central Palisade were documented. Dalan's results indicate that the EM31 is capable of detecting palisade trenches, locating bastions and prehistoric fill areas, and identifying historic features (Dalan 1989).

BACKGROUND OF THE CADE 5 SITE

Feature 1 at the Cade 5 site is a hearth that has been partially excavated by UW-L's 1994 fieldschool. The hearth is oval and measures 2.3 meters in north-south length and 1.7 meters in east-west width. It starts at the base of the plowzone, which lies about 25 centimeters below post-settlement alluvium. The feature was bisected on a north-south axis. The western one-half was excavated, while the eastern half was preserved (Theler et al. 1998) as seen in Figure 1 and Figure 2.



Figure 1. The 1994 excavation



Figure 2.

The area that was excavated produced 139.9 kilograms of burned dolomite. Although the excavation was too small to allow for the interpretation of the depositional sequence responsible for the formation of the site, some characteristics were noted. The soil sequence beneath the hearth was found to be complex and varied. Each profile

was different. A portion of the profile seemed to have been filled prior to the construction of Feature 1 through anthropogenic processes (Theler et al. 1998).

The research questions that have been asked about this site include the following:

- 1) What is the temporal range and spatial distribution of Woodland tradition sites in the North Fork of the Bad Axe River Valley?
- 2) Is there evidence to suggest that the Bad Axe drainage was occupied either on a seasonal basis or year round (Theler and Boszhardt 2006)?

METHODOLOGY

Pre-survey Site Evaluation

It is important to evaluate the site prior to geophysical survey (De Vore and Heimmer 1995). The following characteristics of the Cade project area have been noted. The survey area is encompassed within an agricultural field. The terrain is level. Target features are expected to be found within three meters below the surface.

There are no visible interferences such as utility lines or fences that may affect magnetic readings. An old barn is located approximately 19 meters from the south side of the survey location. It is not likely that the barn will cause interference with magnetic signatures.

The ground was moist. A rainstorm passed through the region the night before and saturated the ground. Ions flow more freely in water, so when the soil is saturated with water, the ground will be more conductive. The soil at the survey site is comprised mostly of silt. The field had not been plowed prior to the geophysical survey. Plow-scars from the previous growing season were apparent. Corn stubble covered around 75% of the surface of the ground.

First Electromagnetic Conductivity Survey

The survey was conducted with GF Instruments CM-031 conductivity meter. During the first survey, the instrument was operated in the vertical dipole mode. This is the standard operating mode for the instrument and gives a maximum resolution for the measurements at six meters below the surface. Standard survey methods were employed, including the laying of a grid over the project area. The grid measured 30 meters on the east/west axis by 60 meters on the north/south axis. Data was recorded at three-meter intervals along each transect of the grid. Each transect was located three-meters apart. GPS coordinates were captured for all four corners of the grid.

Frohlich and Lancaster (1986) assessed causes of error that introduce variation in conductivity measurements. It was found that significant variations occurred when changing walking direction while taking readings. Therefore, all readings were taken while walking south to north along each transect, as opposed to making a zigzag pattern.

It was also found that it is important to make sure that the conductivity meter is held at a constant position on the hip in order to keep the instrument at a level height above the surface of the ground. This reduces the chance of measuring a greater or lesser amount of the subsurface while traversing transects (Frohlich and Lancaster 1986, Heimmer and De Vore 1995). To avoid this error during the Cade 5 survey, the instrument was operated by the same person during the entirety of measurement taking.

A portion of the soil conductivity survey was conducted over a known archaeological feature. This feature consists of the hearth located at the Cade 5 site. It was hoped that the known feature in the conductivity survey would act as a proxy to aid in the interpretation of the different soil conductivity signatures at the site.



Figure 3. Taking conductivity measurements



Figure 4. Looking down profile/transect #30

Conductivity data processing

The data that was collected during the survey was transferred into Excel so that it would be in the proper format for easy use with the mapping software, Surfer, by Golden Software. Isoline maps of the soil conductivity values and the inphase values were produced. This allowed for the creation of a model of the subsurface. These maps allowed for analysis of the site and for interpretations to be made.

Results of First Conductivity Survey

Figure 5 displays the conductivity measurements obtained during the first survey. Each time the color ramps on the scale, it indicates an increase of one milliSiemen per meter. Table 1 describes the signatures that typify each soil type. The measurements from Cade 5 range between about 13 to 20 milliSiemens per meter. All of the measurements fall within the soil classification of silt. There are no contrasts that would signal the presence of an anomaly.

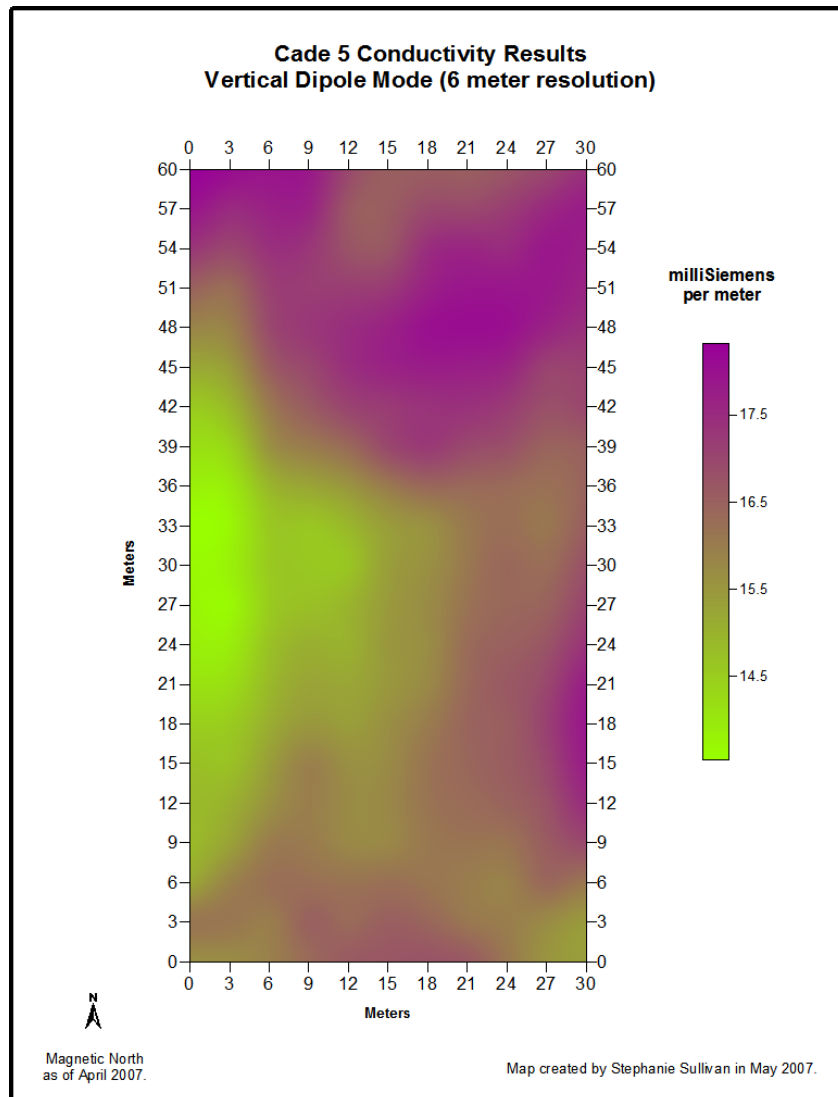


Figure 5. Raster image of vertical dipole mode conductivity values

Table 1. Characteristic conductivity signature for soil type

SOIL	CONDUCTIVITY MS/M
Sand, gravel	0.1 - 1
Silty sand	1 - 5
Loam	5 - 25
Silt	12.5 - 25
Clay	25 - 100
Saline soil	100 - 200

Conductivity compared to Inphase

The conductivity meter also gives measurements for its inphase component. The inphase component is magnetic susceptibility. Figure 6 displays the inphase magnetic susceptibility measurements. Conductivity and inphase are measured simultaneously. The inphase parameter measures the relative size of the real component of the vertical magnetic field which permits detection of buried metal objects. Between the lowest and the highest

values at the survey site, the measurements only vary by 10 parts per thousand. This tells us that the survey area does not contain buried metal objects that might interfere with the conductivity measurements.

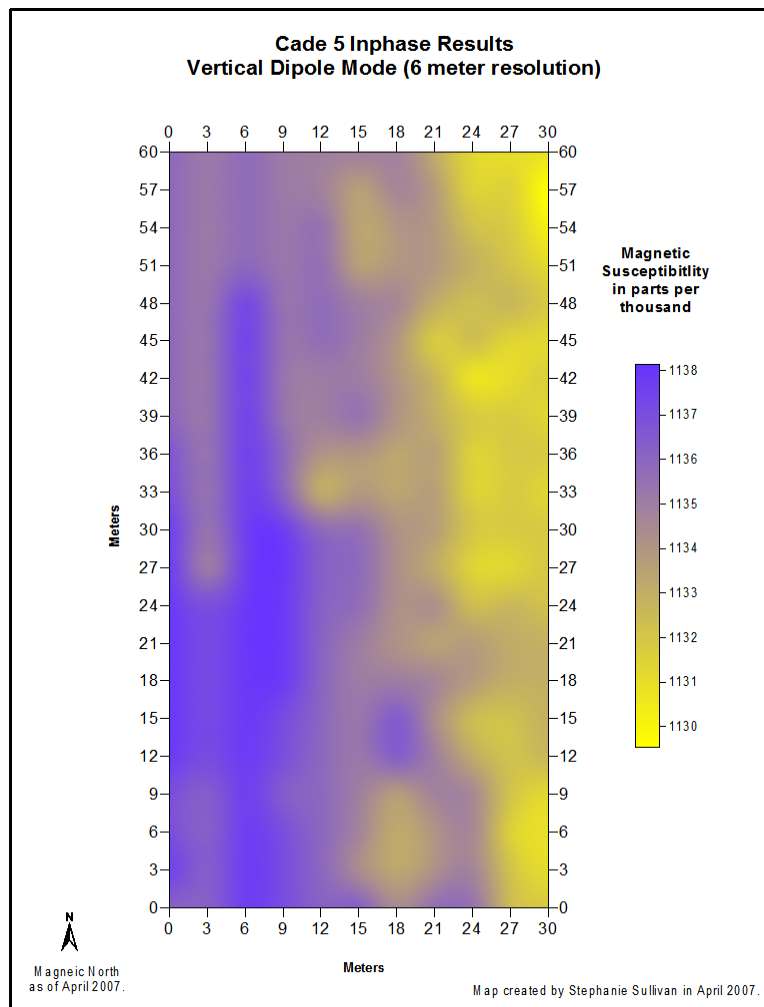


Figure 6. Raster image of vertical dipole mode inphase values

Second Electromagnetic Survey: Conductivity and Inphase Results

A week after completing the first survey, a second survey was conducted. The objective for this survey was to operate the conductivity meter in the horizontal dipole mode, which measures closer to the surface. This produces readings at a maximum resolution of three meters below the surface. The same grid was used but this time only the southern 30 meter by 30 meter half was surveyed. The result of this survey is once again, no anomalies. The values range between 15 and 21 milli Siemens for the ground conductivity conditions, reflecting the normal soil matrix of the area (Figure 7). The inphase magnetic susceptibility values do not contain any spikes and maintain the range of between 1126 and 1138 parts per thousand that was seen in the first survey (Figure 8).

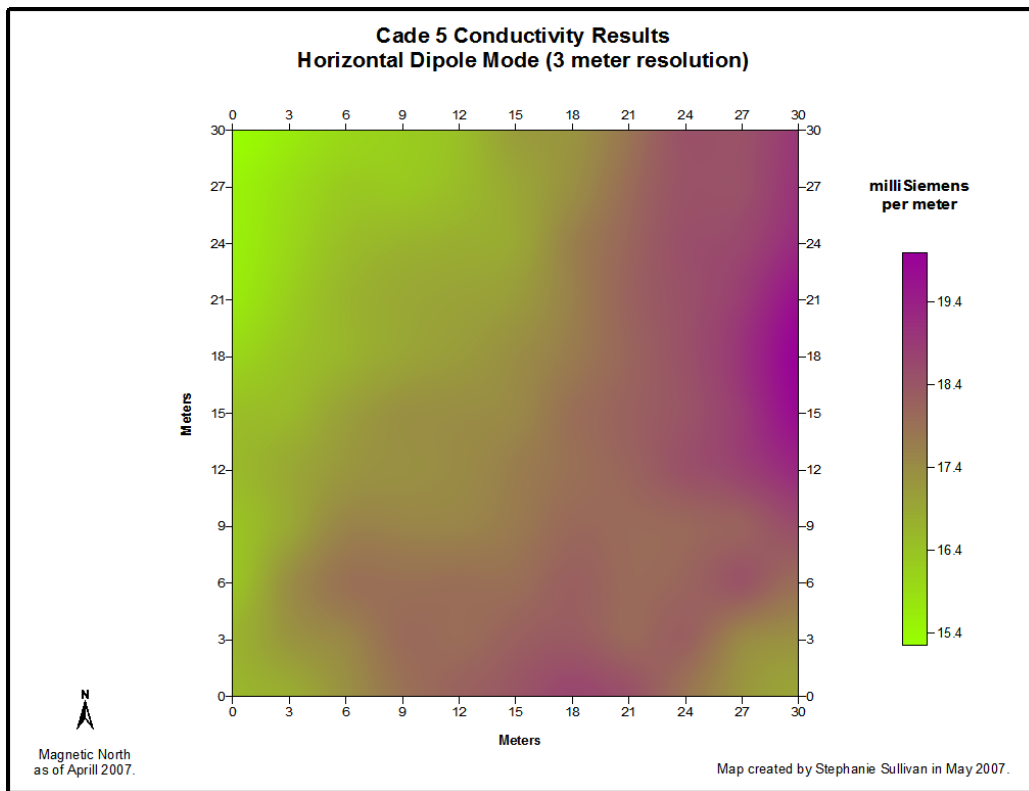


Figure 7. Raster image of horizontal dipole mode conductivity values

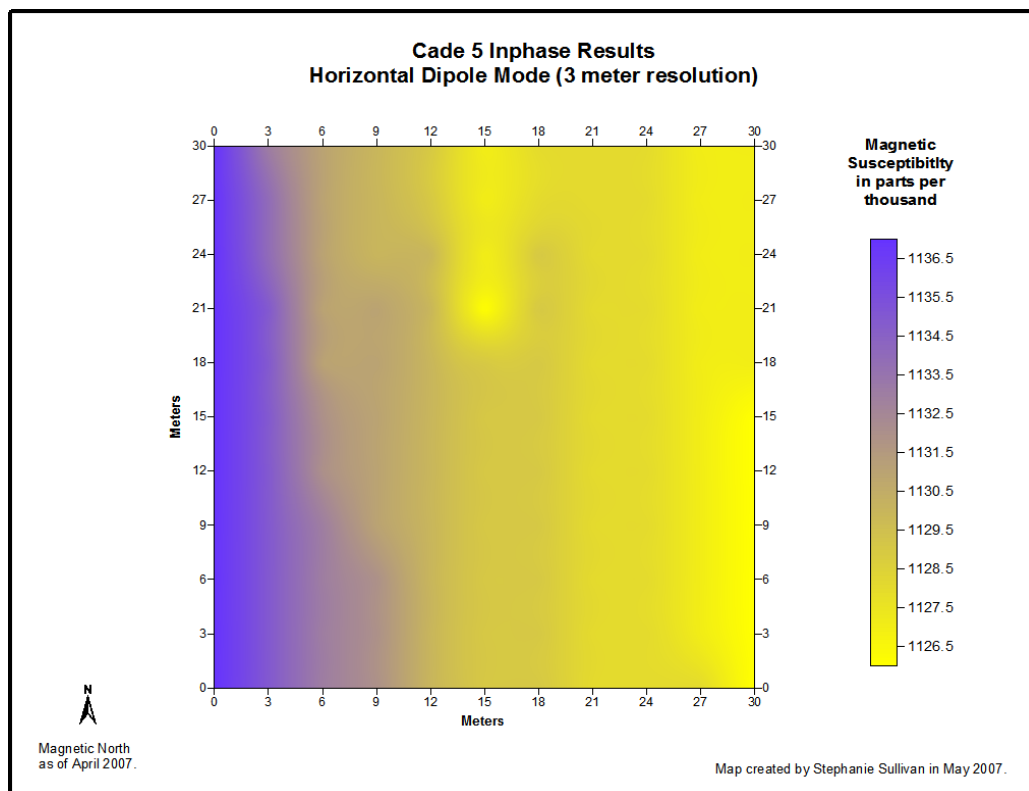


Figure 8. Raster image of horizontal dipole mode inphase values

Magnetic Susceptibility Survey

The original plan for this project was to use the MS2 magnetic susceptibility meter to further explore any anomalies that may have been found. Since no anomalies were detected, it was decided that a few measurements would be taken with the MS2 in order to gain a better understanding of its use in the field.

The MS2 has a suite of probes that can be attached to the meter in order to explore a full range of geologic conditions. However, each probe is quite expensive and must be purchased separately. Currently, UW-L owns the MS2C core logging sensor for measuring sediment cores in a lab and the MS2F probe for high resolution surface measurements. Since the F probe is for use in the field, that is the sensor that was used. This probe is best suited for taking measurements of soil profiles on exposed soil walls. During this project, it was only used on the surface of the ground (Figure 9). The measurements that were taken reflect the plowzone horizon and are not archaeologically significant.



Figure 9. Taking surface measurements with the MS2F probe

CONCLUSION

Three different soil signatures were expected to be found during the surveys. These expected signatures are the following: 1) the normal soil background (characterized by the signature for silt), 2) the disturbed ground where excavation took place and, 3) the remainder of the hearth that is still intact (characterized by anomalous soil signatures). In order to meet the first objective, it was also hoped that additional anomalies would be found in the rest of the survey area. However, these expectations were not produced in the results.

The second objective was to employ a new method of survey in the Cade Archaeological District that may contribute to the understanding of the spatial distribution and expansion of the Late Woodland people in the area. It has been determined that the CM-031 conductivity meter is too large to be used to detect prehistoric features that tend to be found within the first two meters below the surface. Although it is possible for this instrument to be used for archaeological purposes, its parameters are not suited for use at the Cade 5 site.

The third objective of this project was successfully met. A better understanding regarding the archaeological applications of the geophysical equipment available at UW-L was gained. Although this project did not return the results that were hoped for, the results are still valuable. To quote Berle Clay (2007),

“It cannot be stressed too strongly that, to effectively use geophysical survey techniques in archaeology, they must be “used.” This is a cryptic way of saying that it takes a lot of field experience to gain confidence in one’s results so that they can become a really effective adjunct of the archaeologist’s tool kit.”

DISCUSSION

This project was limited by the equipment that is currently available (as of 2007) at UW-L. It put to test the use of the CM-031 for archaeological purposes. The water table was encountered at a depth of 1.5 meters during the 1994 excavation of the hearth at Cade 5 (Theler et al. 1998). Therefore, features are most likely to be found in the shallow subsurface in the Cade Archaeological District. The CM-031 was found to be unsuccessful in detecting such features. Therefore, it is the author’s recommendation that if future geophysical research is to be conducted for archaeological purposes in a similar environment, a more suitable instrument be employed. One instrument that may be considered is the EM38 produced by Geonics. This electromagnetic conductivity meter has a maximum resolution at a depth of 1.5 meters in the vertical dipole mode and a depth of .75 meters in the horizontal dipole mode.

The MS2 could be properly outfitted for archaeological prospecting by purchasing, or renting, a more suitable probe or sensor. The MS2H down-hole magnetic susceptibility logger has been designed specifically for archaeological needs. The author feels that the MS2H used in conjunction with the EM38 may produce the results that were hoped for in this project.

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