2007

Getting Your Hands a Little Less Dirty: An Exercise in Using Geophysics to Understand Hopewell Earthwork Construction

Erin C. Dempsey
erin_dempsey@nps.gov

Getting Your Hands a Little Less Dirty: An Exercise in Using Geophysics to Understand Hopewell Earthwork Construction

Erin C. Dempsey

Abstract: *Hopewellian earthworks are extremely complex in their make-up and indicate precise and planned soil placement by participants in the Hopewell culture. As such, recent research at the Hopeton Earthworks in Chillicothe, Ohio has focused on understanding how earthworks were constructed. Eight backhoe trenches excavated through the earthwork walls have revealed intricate and diverse soil stratigraphy. However, researchers do not yet know where the soils originated; this study aims to answer that question. To accomplish this, magnetic susceptibility testing was conducted on soil cores taken from in and around the earthworks. These results are compared to susceptibility testing results done on trench profile walls in order to identify where soil matches occur. This paper outlines the methods and results of this study.*

Introduction

Almost two thousand years ago, participants in the Hopewell culture of the Middle Woodland Tradition constructed large earthworks and mounds across the eastern United States. This paper focuses solely on the Ohio Hopewell, who resided in floodplains and river valleys throughout that state. Archaeologists have only a limited understanding of the function and use of these earthen structures, and generally identify such sites as elaborate examples of ceremonialism in the Hopewell culture. Such a vague identification, however, leaves researchers with many questions regarding the exact reasoning behind these large structures. Indeed, the physical process of earthwork construction itself has yet to be fully understood and evaluated.

A large concentration of Ohio Hopewell earthwork sites occurs in southern Ohio, specifically within the Scioto River and Paint

Creek locales. Enclosures at Hopeton, Hopewell, High Bank, Seip, Mound City, and other locations are prime examples complex earthwork construction. Unfortunately, intensive agricultural processes over the last 150 years have massively damaged or even destroyed most of these earthworks. However, since they were initially surveyed in 1848 by E.G. Squier and E.H. Davis, these earthworks have been the target of much archaeological investigation. These investigations have ranged from identifying habitation sites in or around the earthworks (Dancey & Pacheco 1997; Bernardini 2004) to deconstructing earthwork wall sections (Lynott 2005) to studying the general pattern of earthworks across the region as they relate to astronomical events (Romain 2000).

One avenue of research that has recently been undertaken is the physical composition and construction of earthwork walls (i.e., the soil color, texture, and origin). This paper focuses on research of this type that was undertaken by the National Park Service and the Midwest Archeological Center at the Hopeton Earthworks, one of the five sites that comprises Hopewell Culture National Historical Park in Chillicothe, Ohio. This research utilizes geophysical (i.e., magnetic survey) and geoarchaeological techniques in the study of earthwork construction.

The present study compares and contrasts the results of magnetic susceptibility testing on geomorphological soil cores taken from in and around the Hopeton Earthworks with the results of the same testing on profile walls of trenches excavated through the earthwork walls. The goal of this study is to determine if soils in the walls of the earthworks can be sourced to the natural soils present in the cores. If this is true, a source-material database can be created to correlate specific wall soils with the location of their natural counterparts, possibly identifying the origins of the wall soils. If this is unsupported, however, it becomes more likely that the builders brought soil in from another location. This would make soil an even more important aspect of earthwork construction and utilization.

This study is a contribution to the body of knowledge, archaeological and otherwise, that is being accumulated on the Hopeton Earthworks specifically and the Hopewell culture in general. It is hoped that this study will help pave the way for future studies with similar methods and goals. The application of new technology in archaeology is vital to obtaining new data, especially at sites where old methods of research have been exhausted and research questions have shifted focus.

Site Description

The Hopeton Earthworks, located on the floodplain of the Scioto River, are large, connected earthen structures containing a rectangular or square enclosure and a circular enclosure, each of which contains approximately 20 acres of land. Two small circular enclosures are present on the east side of the rectangle and a set of parallel walls extend from the northwest corner of the square, 2400 feet to the southwest of the site (Figure 1). At the time of its first mapping, the walls of the circle stood six feet above the ground while the walls of the rectangle stood at a daunting 12 feet high (Squier & Davis 1848).

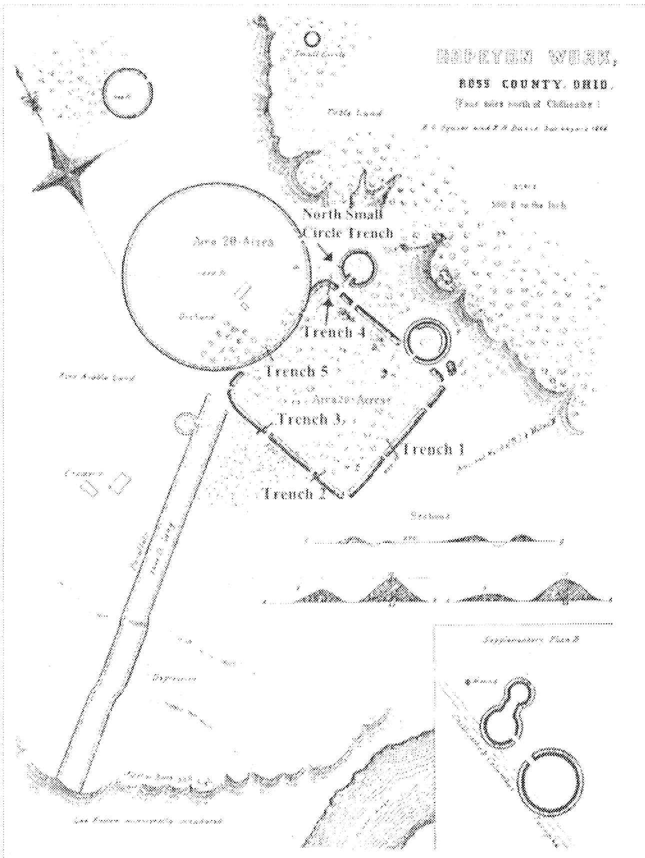

Figure 1. Map of the Hopeton Earthworks (Squier and Davis 1848). The image also depicts the eight backhoe trenches dug at the site.

The work conducted at Hopeton is multi-disciplinary in nature, involving archaeological, geophysical, and geoarchaeological specialists, all working in concert to build a body of knowledge on the construction of the earthen walls that comprise the Hopeton Earthworks. Over the last five years, eight trenches have been excavated through the extant earthwork walls at this site; these excavations revealed that the walls were not built randomly and that the soils used were laid down carefully and precisely, using various colors and textures of soils (Lynott 2006). What this purposeful selection and placement of soil may reflect, be it the ceremonial nature of the enclosures or some meaning within the Hopewell culture, has not been identified.

To aid in the archaeological investigations of the earthworks, magnetic susceptibility testing was conducted along a profile wall in each of the trenches in order to measure the subtle differences in soil. This type of testing will be discussed in detail below. Additionally, 25 geomorphological soil cores were extracted from the site in 2004 and 2005. These cores were excavated in areas where soils occur naturally on the landform in an effort to determine the natural stratigraphy of the site and whether or not the soils that make up the earthwork walls originated at the site. Also of importance, a large geophysical database has been built of Hopeton, the largest portion of which includes data from magnetometer survey (Lynott 2006). The site-wide magnetometer testing provides researchers with an excellent view of the site layout from the perspective of magnetic versus non-magnetic soils.

Magnetic Susceptibility

One of the most important advancements in archaeology came with the use of various types of geophysical investigation. Of these methods, magnetic studies have been extremely successful in seeing what lies beneath the surface. At Hopeton, magnetometer survey has been used to distinguish the layout of the earthworks and magnetic susceptibility survey has been conducted to determine the differential placement of soils comprising the earthwork walls (Dalan 2003, 2004, 2005). This paper reports exclusively on the latter type of survey.

Magnetic susceptibility is a measure of the degree to which a substance can be magnetized (Dalan & Banerjee 1998). It is only measurable in the presence of a magnetizing field and is defined as the ratio of the induced magnetization to the magnetizing field (Clark 2001; Dalan and Banerjee 1998). Magnetic susceptibility can be expressed as either mass susceptibility (χ), normalized by mass, or as volume susceptibility (κ), normalized by volume. This type of magnetic survey is most useful in situations where the topsoil has been disturbed and is especially adept at identifying evidence of occupation (Clark 2001). Magnetic susceptibility is also useful in separating soil horizons, sedimentary sequences, and culturally modified areas of soil (Dalan 2001) as well as detecting where subtle, but important, changes in soils occur (Weston 2002). The present study utilizes mass-specific measurements (meaning values that are normalized via the mass of an individual soil sample), which are expressed by the equation $\chi = \kappa/\rho$, where ρ is the density of the material (Clark 2001).

When conducting magnetic susceptibility in the laboratory, both low (470Hz) and high frequency (4700 Hz) measurements are taken. This measures the "susceptibility spectrum," a measure of the variability of susceptibility with grain size and frequency changes (Clark 2001:103). In general, the low frequency values are used in analysis by convention and characterize the soil on a finer scale than the high frequency values (Dalan, personal communication 2006). By testing each sample at two different frequencies, a frequency dependency ($\chi_{fd\%}$) value can be obtained for an individual soil sample via the equation

$$\frac{\text{low frequency} - \text{high frequency}}{\text{low frequency}}$$

which produces a value that is expressed as a percentage. A low frequency dependency value indicates soil that has been weathered from bedrock and contains large grains, while a high frequency dependency value is produced by the presence of small magnetic grains in soil, indicative of an alluvial depositional environment (Dalan, personal communication 2006). It is presumed these grains were produced in a primarily alluvial depositional environment because of the site's location in the floodplain of the Scioto River. According to Dalan (personal communication 2006), a low (insignificant) frequency dependency of 0-4% indicates large-grained soils. A high (significant) frequency dependency would be in the range of 10-15% and indicative of fine-grained soils. In this study, values of 5-9% are considered significant and represent soils whose fine grains are indicative of some sort of deposition event.

Clark (2001) notes that frequency dependency is a good indicator of how soils are modified, either naturally or culturally. He states that "sites of human activity will be distinguished as areas of high susceptibility accompanied by increased frequency dependence" (Clark 2001:103). However, determining if soil deposition has been a cultural or natural event is subjective and often difficult to determine (Dalan, personal communication 2006). Therefore, this study only attempts to identify which soils *may* have been culturally modified.

Magnetic susceptibility is useful for differentiating soils based on their magnetic properties (Dalan & Banerjee 1998). It can also be used to determine boundaries between archaeological features and the surrounding undisturbed soils. Such a technique is also useful in investigating site formation processes, erosion events, stratigraphy, and site boundaries, and has recently proven to be adept at fine-scale feature study (Dalan, personal communication 2006). At Hopeton, magnetic susceptibility has been used both in the field and in the laboratory to identify culturally modified soils and the movement of those soils across a site and also to support the findings of other magnetic survey results. According to Dalan and Bevan (2002), the culturally modified soils that comprise earthwork walls may have different magnetic properties than the surrounding, undisturbed soils.

Methods

The 23 soil cores collected from the Hopeton Earthworks during the summer of 2004 and 2 cores from the summer of 2005 were divided into horizons, layers of soil, and sub-horizon by Dr. Rolfe Mandel of the Kansas Geological Survey. For this study, a core is defined as “a continuous section of soil or rock obtained by using a hollow cylinder called a corer or coring device” (Stein 1986:505). During sampling, it was decided that samples would not be taken from the C horizon as this horizon is usually homogenous and sterile and values would not provide useful data, although in retrospect, sampling the C horizon would have provided the background from which the A and B horizons were developed. Thus, the collection comprised 118 soil samples from the various sub-horizons of the A and B horizons. The maximum number of samples taken from any one core was nine while the minimum was two. Soil from each bag (containing one horizon from one core) was packed into a single ¾” Althor P15 plastic box (5.28cc volume).

Lab magnetic susceptibility survey was conducted using a Bartington Instruments MS2 susceptibility meter, MS2B lab quality sensor, and the Multisus software provided by Bartington Instruments. A particular measurement protocol was followed to avoid readings affected by instrument drift. First, the susceptibility sensor was zeroed. Then, the sample was inserted into the machine and measured for low frequency (470 Hz) susceptibility. Low frequency susceptibility is observed when magnetization is introduced to a sample in the presence of a small magnetic field similar to the Earth's which provides a measure of the degree to which the soil can be magnetized (Dalan 2004). The sample was then removed and the instrument was zeroed again. This was completed with each of the 118 samples, comprising Set 1. After the low frequency measurements were completed, the instrument was switched to high frequency (4700 Hz) susceptibility. The same sequence of events was undertaken to obtain high frequency measurements on the samples. Once the high frequency measurements were taken, the program calculated the frequency dependency ($\chi_{fd\%}$). The samples were then measured again to obtain an average of two readings to determine the low and high field magnetic susceptibility. The resulting values were normalized by the Multisus program according to the mass of the sample in order to yield mass magnetic susceptibility values (χ).

After the primary data collection (known as Set 1), two additional sets of samples, Sets 2 and 3, were collected in the same manner as Set 1 and then tested for susceptibility. These additional sample sets were obtained to control for the variability exhibited within each soil horizon and to mitigate the bias of only having taken one sample from a large bag of soil. One difference in the collection of susceptibility readings for Sets 2 and 3 was that, due to time constraints, only one set of low and high frequency values and frequency dependency percentages was obtained for each set. Therefore, these two sample sets do not represent averaged values.

After the magnetic susceptibility results were calculated, corrected low frequency susceptibility values were obtained by multiplying the Bartington units (the units of output in the Multisus program) by 1.015×10^{-9}, which corrected for the shape of the sample box. The final step of the data analysis was to graph the low frequency results for all three sample sets using the Golden Software Grapher 6 computer program.

Results

Of the 25 cores, six cores from 2004 (1, 3, 4, 11, 12, and 19) were chosen for close examination and discussion (Figure 2). Cores 1, 3, 4, and 19 were selected because of their proximity to trenches. Dr. Rinita Dalan has obtained susceptibility values from the wall profiles of these trenches and thus, comparisons were made between these existing data and the new data obtained from the cores. Core 11 and 12 give an idea of the spread of the susceptibility values across the site. An important factor is that the following results and comparisons use only the low-frequency (or low-field) mass susceptibility values from sample Set 1. The low-field values were used as they represent the more accurate and precise of the two types of values. The discussions on variability include sample Sets 1, 2, and 3. Also, all values are in m^3/kg units and, as mentioned earlier, are corrected for shape.

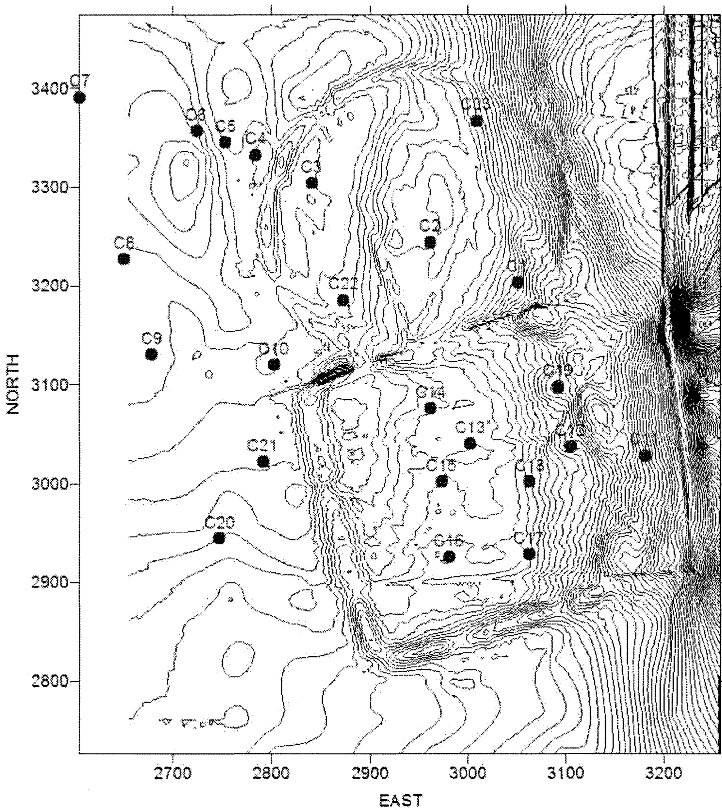

Figure 2. Hopeton Topographic Map and Geomorphological Core Locations. This map shows the 2004 core locations at the Hopeton Earthworks, but does not include the 2005 cores. (Lynott 2005).

For each of the cores, readings from all three sample sets were graphed together to determine the variability within each horizon of each core, in an attempt to address the degree of disturbance that may be present in each horizon. Unfortunately, as each core was not sampled in a vertically continuous manner, it is not possible to identify depths at which various changes in susceptibility occur, only the horizon. By taking several samples from each horizon, it may be possible to say whether or not a significant amount of disturbance has taken place or if a dramatic change in the type of soil is present and characterize that horizon accurately. Elements such as bioturbation, rodent or earthwork disturbance, weathering, erosion, and human disturbance may affect variability within each horizon. Determining if such disturbance exists can lead to more questions about what caused the disturbance, and therefore the change in susceptibility values.

Table 1 presents the raw magnetic susceptibility values obtained from each of the selected cores. Following that, a brief synopsis of each core is given to outline what its susceptibility values indicate. In these synopses, correlations are made from those values to the types of soils found in that portion of the site and when possible, comparisons are made to Dalan's (2006) trench susceptibility values. The variability of the susceptibility values from the various horizon depths is addressed as is the core's overall frequency dependency.

Core 1: The susceptibility values from Core 1 demonstrate the type of susceptibility distribution expected for an area where soils are most likely not culturally modified. This core is located in the circular enclosure, close to the confluence of the circle and square and to the section of earthwork wall through which Trench 8 was dug during the summer of 2005 and the values from Dalan's (2006) data of susceptibility taken across the profile of this trench's wall are similar to those values obtained from the core. In this particular core, the variability in the values from sample Sets 1, 2, and 3 is insignificant. The frequency dependency in this core has a range that does not suggest the presence of modified soils.

Core 3: Core 3 is located near Trench 7 and was taken from inside the circular enclosure, on the west side. As compared to Dalan's (2006) data from Trench 7, it is possible that some of the soils observed in this core were used in wall construction. Though there was not much variability among the three sample sets for this core, Set 1 does contain a value in horizon Bt1 that is quite a bit lower than the same horizons in Sets 2 and 3 indicating that one of the values is flawed. The frequency dependency values in this core are curious considering that the most modified soil, according to the breakdown of frequency dependency values explained earlier, occurs in the second, or Bt1, horizon. Because of its proximity to the earthwork wall, it is possible that the core went through a truncated soil profile (Dalan, personal communication 2006).

	Horizon	Depth (cm below surface)	Sample Set 1	Sample Set 2	Sample Set 3	Freq. Dependency (Set 1 only)
Core 1	Ap	0-20	2.10E-06	2.24E-06	2.06E-06	2.81%
	Bw1	20-45	2.20E-06	2.41E-06	2.34E-06	3.08%
	Bw2	45-80	1.71E-06	1.75E-06	1.87E-06	1.07%
	BC	80-130	1.68E-06	1.78E-06	1.83E-06	2.37%
Core 3	Ap	0-23	1.11E-06	1.26E-06	1.11E-06	9.10%
	Bt1	23-35	3.45E-07	1.00E-06	9.12E-07	10.20%
	Bt2	35-90	2.99E-07	3.35E-07	3.41E-07	10.47%
	BCt	90-110	7.53E-07	1.09E-06	1.17E-06	0.67%
Core 4	Ap	0-22	1.44E-06	1.57E-06	1.64E-06	7.30%
	AB	22-33	1.74E-06	1.62E-06	1.66E-06	8.12%
	Bw1	33-55	1.82E-06	1.71E-06	1.79E-06	7.34%
	Bw2	55-70	1.76E-06	1.60E-06	1.82E-06	9.18%
	BC	70-90	1.13E-06	1.43E-06	1.35E-06	3.39%
Core 11	Ap	0-20	2.17E-06	2.26E-06	2.13E-06	0.93%
	A	20-30	2.18E-06	2.38E-06	2.23E-06	4%
	AB	30-45	2.32E-06	2.34E-06	2.12E-06	0.74%
	Bw	45-98	1.81E-06	1.83E-06	2.39E-06	2.62%
	BC	98-112	1.25E-06	1.18E-06	1.84E-06	2.68%
Core 12	Ap	0-21	1.87E-06	1.95E-06	1.89E-06	4.14%
	Bw1	21-55	1.24E-06	1.07E-06	1.34E-06	5.14%
	Bw2	55-76	6.11E-07	5.82E-07	6.65E-07	-1%
	BC	76-105	9.92E-07	1.37E-06	1.34E-06	-1.43%
Core 19	Ap	0-21	2.11E-06	2.17E-06	1.44E-06	3.47%
	Bw1	21-40	1.31E-06	1.46E-06	2.07E-06	2.62%
	Bw2	40-60	1.42E-06	1.73E-06	1.37E-06	2.07%
	BC	60-85	4.66E-06	3.33E-06	1.65E-06	1.28%

Table 1. Raw results of magnetic susceptibility testing.

Core 4: Core 4 is located on the outside of the northwest part of the circular enclosure, on the opposite side of the earthwork wall from Core 3 but still near Trench 7. The values obtained from this core are higher than those values obtained by Dalan (2006) in Trench 7. The middle three horizons (AB, Bw1, and Bw2) have higher values than the same horizons in Sets 2 and 3. Thus, there is not much variability between Sets 2 and 3, while there is some variability between Set 1 and the other two. This core's frequency dependency has a distribution similar in spread but higher in value then was encountered in Core 3. As this core is located outside the earthwork, it makes for an interesting comparison to Core 3; while Core 3 is truncated, possibly by wall construction (due likely to removal of material), Core 4 is more enhanced, possibly identifying a pattern in susceptibility between the inside and outside of the earthwork.

Core 11: Core 11 is located on the east side of the rectangular enclosure, though not close to any excavated trenches; it is near the two small circular enclosures on the outside of the square enclosure. The core susceptibility values in Set 1 indicate that the upper horizons are more magnetic than the lower horizons. In looking at the range of values, the variability among the three sample sets in this core is more pronounced. The frequency dependency values, as in Core 1, do not indicate overly modified soils.

Core 12: Core 12, though not located near any trenches, is in the eastern part of the rectangular enclosure. In this core, values are highest in the upper horizons, hit their lowest point in the Bw horizon and then rise again in the BC horizon. The variability among the data sets in this core was minimal. This core exhibits frequency dependency values similar to those in Cores 1 and 11, which do not indicate drastically modified soils.

Core 19: Core 19 is located north of Core 12 in the eastern portion of the rectangular enclosure. Although they are not close to each other, Core 19 contains susceptibility values similar to those in Trench 1 where a deep red soil was encountered below the topsoil (Mandel 2003). The jump in value size from the core's topsoil to subsoil could be explained by the presence of the deep red soil observed in Trench 1. The three sample sets from this core exhibit similar values and do not demonstrate a significant degree of variability. The frequency dependency values in this core indicate soils that are not overly modified. This core is interesting because of the wide range of values;

this may be indicative of feature (Dalan, personal communication 2006).

Discussion

In Cores 1 and 4, the susceptibility values were similar to those values present in Trenches 8 and 7, respectively. These similarities may indicate that the soils in these areas of the site were not used in earthwork wall construction. If these soils were used to form the earthwork wall, dissimilar susceptibility values would be expected as the soil in the core would have then become the soil used in the wall, which may have been indicative of the removal of topsoil to form the earthwork walls. In Core 3, the susceptibility values were only somewhat similar to those present in Trench 7. This could indicate an area where soils were mixed or modified either before or after wall construction. Whether or not the soils in the cores are present in the walls is uncertain. Cores 11 and 12 are not located close to any of the eight trenches. These cores were examined because they provided an idea of the spread of susceptibility values across the site. The frequency dependency of these cores is not indicative of intensive modification. Core 19, though it is located close to Trench 4, contains susceptibility values similar to those found in Trench 1. This could indicate an area where a red soil found in the trench, which produced a unique susceptibility signature, was quarried.

The frequency dependency values exhibited by all six cores are extremely variable in the degree of modification. Many of the other cores, not discussed at length in this paper, including Cores 9, 10, 13, 20, 21, 22, and 2005-1, have high frequency dependency values ranging between 7 and 11%. This is indicative of highly modified soils. Most of these cores (except 13 and 22) are located outside of the earthen enclosures. The soils in these cores could have been disturbed during the quarrying of top soil from outside the earthworks.

The distribution of magnetic susceptibility results from the trenches dug at the site indicates several things, including that the topsoils in this area of the site were stripped to expose a red sandy loam subsoil (Dalan 2004). The idea that the site was stripped of its topsoil prior to construction has been evidenced in other trenches as well as in the core samples (Lynott 2005). As this is evident elsewhere at the site, it is likely that the earthwork walls were constructed out of soil fills located on top of a subsoil base (Dalan 2004). The soil at the core of this and other trenches have low susceptibility values while higher susceptibility values are found in the soils on the outside earthwork. A third type of soil, a topsoil, caps the earthworks but most likely formed after the earthworks were constructed (Lynott & Mandel 2006).

In all, three types of soils are encountered at the site and each has a different magnetic susceptibility value which allows for identifying the placement of soils according to their susceptibility values. The three soils can be related to three colors, yellow, red, and gray-brown (see Bernardini 2004 and Lynott 2005 for more information). The yellow soils were used as the core of the earthwork walls, while the red soil was placed on the outside of the walls. The gray-brown soil represents the topsoil that formed after construction. In some instances, the placement of the red soil varies, suggesting even greater complexity in the Hopewell's construction sequence and may speak to color symbolism within the culture.

In comparing the results of the core magnetic susceptibility testing with the magnetic susceptibility results of testing in the trenches, at least some of the soils located in the earthwork walls could have come from within or very near the earthwork itself. The susceptibility values from various horizons within the core samples are similar in strength to points along the trench walls. The core susceptibility values also indicate that, while the higher susceptibility soils are located in the upper horizons, the lower susceptibility soils are in the lower horizons. The soils with low susceptibility values in the center of the earthwork walls, then, could have been obtained when the topsoil was stripped off of the site. The comparison between the mass susceptibility values obtained from the cores and those taken from within the trenches demonstrates a consistent and reliable method of measuring the susceptibility of the soils and also the presence of similar soils in both the trenches and the cores.

As a caution, more interpretive work with the susceptibility testing results presented in this paper is necessary to make greater inferences about the soil profile that exists at the site. The results discussed above are only preliminary. Much more can and should be done with this data than is presented here. Because of the venue in which this paper is presented, it is not possible to provide the almost 40 pages of graphs and charts necessary to fully understand what is discussed above. To view this data, please feel free to contact the author.

Conclusion

The success of soil magnetic studies at the Hopeton Earthworks has allowed for greater characterization and definition of the types of soils found at the site and the locations of these soils

(Dalan 2005). Soil placement was a specific and intentional event for the people who built the earthworks (see Bernardini 2004; Lynott 2002). Understanding where the soils were obtained and how they were used in the construction of the earthworks allows for greater insight into the Hopewell culture.

The results of this study and other similar research conducted at the site, demonstrate that magnetic studies help differentiate where natural versus culturally modified soils occur at the site. These studies help determine whether or not the soils used in earthwork wall construction were taken out of their original context at the site or if they were brought in from another location. The magnetic susceptibility testing undertaken in the present study identifies areas in and around the earthworks that may have been stripped of topsoil, which was then used for constructing the earthworks themselves, as evidenced by differing magnetic signatures between the earthwork walls and the cores. It also identifies areas where the magnetic signatures of the earthwork walls and the cores were similar, possibly indicating areas where soil-quarrying activity occurred for constructing the earthworks.

The database of magnetic data for the Hopeton Earthworks is extensive and is the basis of a significant amount of knowledge about the physical makeup of the site. Continued studies of this nature will only add to this knowledge and further the advancement of geophysical and geoarchaeological investigation, not only at the Hopeton Earthworks, but also at other earthwork or Hopewell sites in general. Magnetic susceptibility works well at this site because it is able to differentiate between the subtle soil layers that compose the earthwork walls.

The Ohio Hopewell paid great attention to the details of soil placement, color, and possibly texture. As such, it is vital to the continued study of earthwork sites for archaeologists to try to understand how these soils were used in constructing earthen walls. Through an understanding of how the physical feat of earthwork construction was accomplished and perceived or experienced in the Hopewell culture, we can better understand the meaning behind the construction and use of such impressive structures.

Acknowledgements

Many people were significantly involved in the formulation and writing of this paper. Many thanks goes to Dr. Rinita Dalan (Minnesota State University Moorhead), Steve DeVore (Midwest Archeological Center), Dr. Mark Lynott (Midwest Archeological Center), Dr. Rolfe Mandel (Kansas Geological Survey), and Dr. LuAnn Wandsnider (University of Nebraska-Lincoln) for sharing with me their ideas, criticisms, interpretations, wisdom, and time. I am especially grateful to Dr. Lynott for allowing me to be part of such exciting work and for sparking my interest in all things Hopewell. Thanks also goes to the editors of this volume for their valuable time, insight, and friendship. Any errors or inconsistencies found in this paper are solely my responsibility.

References Cited

Bernardini, Wesley
2004 Hopewell geometric earthworks: a case study in the referential and experiential meaning of monuments. *Journal of Anthropological Archaeology* 23:331-356.

Clark, Anthony
2001 *Seeing Beneath the Soil*. Routledge, London.

Dalan, Rinita A.
2001 A Magnetic Susceptibility Logger for Archaeological Application. *Geoarchaeology* 16:263-267.
2003 Soil Magnetic Studies of the Hopeton Earthworks, 2002 Excavations. On file, Midwest Archeological Center, Lincoln, NE.
2004 Magnetic Susceptibility Studies of the Hopeton Earthwork, 2003 Excavations. On file, Midwest Archeological Center, Lincoln, NE.
2005 Magnetic Susceptibility Studies Within Trenches 6 and 7 at the Hopeton Earthworks. Report on file, Midwest Archeological Center, Lincoln, NE.
2006 Magnetic Susceptibility Values from Trenches 1-8. Personal correspondence, March 2, 2006.

Dalan, Rinita A., and Subir K. Banerjee
1998 Solving Archaeological Problems Using Techniques of Soil Magnetism. *Geoarchaeology* 13:3-36.

Dalan Rinita A., and Bruce W. Bevan
2002 Geophysical Indicators of Culturally Emplaced Soils and Sediments. *Geoarchaeology* 17:779-810.

Dancey, William S., and Paul J. Pacheco
1997 Community Model of Ohio Hopewell Settlement. In *Ohio Hopewell Community Organization*, edited by William S. Dancey and Paul J. Pacheco, pp. 3-40. The Kent State University Press, Kent, OH.

Lynott, Mark J.
2005 The Hopeton Earthworks. Paper presented at the 70th Annual Society for American Archaeology Conference, Salt Lake City, Utah.

Lynott, Mark J., and John Weymouth
2002 Preliminary Report, 2001 Investigations, Hopeton Earthworks. *Hopewell Archeology* 5(1): 2002.

Lynott, Mark J., and Rolfe Mandel
2006 Geoarchaeological Study of the Hopeton Earthworks. Paper presented at the Geological Society of America Annual Conference, Philadelphia, Pennsylvania.

Mandel, Rolfe D.
2003 Stratigraphy, Lithology, and Pedology of the South Wall at the Hopeton Earthworks, South-Central Ohio. Kansas Geological Survey Open File Report 2003-46.

Romain, William F.
2000 *Mysteries of the Hopewell: Astronomers, Geometers, and Magicians of the Eastern Woodlands*. University of Akron Press, Akron, OH.

Stein, Julie K.
1986 Coring Archaeological Sites. *American Antiquity* 51:505-527.

Squier, E.G., and E.H. Davis
1884 *Ancient Monuments of the Mississippi Valley*. Smithsonian Institution Press, Washington D.C.

Weston, D.G.
2002 Soil and Susceptibility: Aspects of Thermally Induced Magnetism within the Dynamic Pedological System. *Archaeological Prospection* 9:207-215.