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# Native American Occupation of the Singer-Hieronymus Site Complex: Developing Site History by Integrating Remote Sensing and Archaeological Excavation

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Native American Occupation of the Singer-Hieronymus Site Complex: Developing Site History by Integrating Remote Sensing and Archaeological Excavation

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by

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ABSTRACT

Native American Occupation of the Singer-Hieronymus Site Complex: Developing Site History by Integrating Remote Sensing and Archaeological Excavation

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Located on a ridgetop in central Kentucky, the Singer-Hieronymus Site Complex consists of at least four Native American villages. The Native Americans who lived there are called the "Fort Ancient" by archaeologists. This study examined relationships between these villages, both spatially and temporally, to build a more complete history of site occupation. To do this, aerial imagery analysis, geophysical survey, and archaeological investigations were conducted. This research determined there were differences among villages in terms of their size, however other characteristics—internal village organization, village shape, radiometric dates, and material culture—overlapped significantly. Additionally, landscape-scale geophysical survey identified at least three potentially new villages. It has been suggested that Fort Ancient groups abandoned villages every 10 to 30 years due to environmental degradation, but these results suggest that native peoples did not abandon villages at Singer-Hieronymus. Current thought surrounding Fort Ancient village abandonment and reoccupation must therefore be reconsidered.

DEDICATION

This thesis is dedicated to my paternal grandparents: Claibourne Stanley Sea and Ophelia Elizabeth Overstreet, and my maternal grandparents: Barbara Jane Medley and William Russell Hatchell.

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# CHAPTER 1

# INTRODUCTION

## Statement of Research Problem

Researchers have suggested that Fort Ancient settlement patterns reflect slash-and-burn or "swidden" horticultural practices (Sharp 1990; Henderson 1998, 2008; Raymer 2008). That is, villages move every 10 to 30 years due to environmental degradation triggered by agricultural practices (Raymer 2008). Artifact assemblages and chronometric data reflect breaks in occupation at preferred locales. In the central Kentucky region, many sites support this model (Henderson 1998).

The Singer-Hieronymus Site Complex consists of a series of separate Fort Ancient villages located within 12 ha of an 18-ha ridgetop in Scott County, Kentucky. Investigations conducted on two of the four villages indicate that the locale was occupied during both the Middle and Late Fort Ancient periods (Henderson 1998). Differences in material culture, along with radiometric data between these two villages support a model of episodic occupation at Singer-Hieronymus. The remaining two villages (identified in the late 1990s) were expected to continue this pattern but had never been extensively investigated (Henderson and Pollack 2000).

The Fort Ancient occupational history of the Singer-Hieronymus Site Complex raises interesting questions. 1) What are the temporal relationships of the villages at Singer-Hieronymus? 2) What is the size, shape, and internal organization of these villages? 3) Does Singer-Hieronymus support or contradict a model of episodic occupation associated with slash-and-burn horticultural practices? 4) Are there additional villages at Singer-Hieronymus that can be identified by landscape-scale geophysical survey? My research at Singer-Hieronymus evaluates these questions.

To answer questions regarding the temporal relationships of the Singer-Hieronymus villages, diagnostic material objects and attributes were analyzed for each village, supplemented by chronometric data, in attempt to identify the occupational sequence. Regarding village spatial relationships, remote sensing techniques, including aerial imagery analysis and near-surface geophysical survey, were utilized, along with GIS and archaeological excavation, to determine the size, shape, and internal organization of these villages.

For determining the presence of potentially undocumented villages at Singer-Hieronymus, landscape-scale geophysical survey utilizing electromagnetic induction (EMI) was conducted. EMI is a near-surface geophysical approach that utilizes time-varying electromagnetic fields to simultaneously measure apparent magnetic susceptibility and apparent electrical conductivity (Witten 2006). EMI surveying has been used successfully to identify buried archaeological deposits on sites worldwide (Frohlich and Warwick 1986; Ernenwein 2008; Henry et al. 2014). One consequence of EMI survey is instrument drift, or a destabilization of instrument calibration that can hinder survey results. Drift can be caused from rapid heating and cooling of instrument circuitry and from differing calibration procedures. It has been suggested that by collecting EMI data using specific survey methodologies, instrument drift can be modeled and removed (Delefortrie et al. 2014). Therefore, during the process of identifying undocumented villages at Singer-Hieronymus, a procedure for modeling and removing instrument drift in the EMI data was developed.

## Organization of Thesis

This thesis is in an alternative two-article format. It is organized as follows: Chapter 2 is the first of the two articles. It presents spatial data obtained through aerial imagery, geophysical survey and archaeological investigations, as well as temporally sensitive material culture and radiometric data, in an attempt to sequence the Middle Fort Ancient villages at the Singer-Hieronymus Site Complex. In addition, an argument is made against the interpretation of environmental degradation as a catalyst for its abandonment. Chapter 3 is the second of the two articles. It discusses the geophysical methods used at the Singer-Hieronymus Site Complex and evaluates the successes of a particular method used to map buried archaeological signatures: electromagnetic induction (EMI). Further, a detailed overview of the operation, use, and applicability of the tie-line method for collecting landscape-scale EMI data is provided. Chapter 4 presents the final discussion and conclusions of the thesis. It brings together the main ideas and claims from both papers and discusses their significance. This thesis concludes with closing remarks regarding recommendations for future research.

## CHAPTER 2

# LATE-MIDDLE FORT ANCIENT OCCUPATION AT THE SINGER-HIERONYMUS SITE COMPLEX IN SCOTT COUNTY, KENTUCKY

Claiborne Daniel Sea


## Abstract

The Fort Ancient were Native American farming peoples who inhabited the Middle Ohio Valley between roughly A.D. 1000 and A.D. 1750. It has been suggested that Fort Ancient settlement reflects slash-and-burn "swidden" horticultural practices and that locales were occupied episodically rather than continuously due to environmental degradation. This is supported by an abundance of archaeological data (differences in material culture) and radiometric dates that suggest a long hiatus between occupations. The objective of this study was to examine the temporal and spatial relationships among multiple villages at the Singer-Hieronymus Site Complex to build an occupational history of the site and to attempt to develop an occupational sequence for these villages. To do this, aerial imagery analysis, geophysical survey, and archaeological investigations were conducted. It was concluded that material culture and radiometric data overlapped too greatly to sequence the occupation of these villages. However, this overlap suggests a continuous occupation at this locale, and therefore, that the Singer-Hieronymus Site Complex does not support the slash-and-burn horticultural model. Environmental degradation does not appear to have been the determining factor that led the inhabitants to relocate.


## Introduction

"Fort Ancient" is the term archaeologists apply to the Native American farming peoples who inhabited the Middle Ohio River Valley between roughly A.D. 1000 and A.D. 1750 (Figure 2.1) (Griffin 1943; Essenpreis 1978; Sharp 1996; Drooker 1997; Henderson 1998; Cook 2008). The Fort Ancient people primarily subsisted on maize, supplemented with beans and squash, riverine resources, and big and small game (Breitburg 1992; Rossen 1992). Archaeologists consider the Fort Ancient to be a middle range society, based on both archaeological evidence and ethnographic comparison (Griffin 1992; Henderson 1998). With the exception of low-earthen burial mounds, Fort Ancient communities and Fort Ancient settlement patterns do not suggest sociopolitical hierarchy. Additionally, around A.D. 1200, groups began organizing themselves in circular settlements – a communal organization seen among middle range societies of South America such as the Gê and Mehinaku (Gregor 1980; Mayberry-Lewis 1980; Wüst and Barreto 1999).

Regarding the length of Fort Ancient village occupation, current evidence suggests that one limiting factor may have been environmental degradation of the area surrounding the village. More specifically, through archaeological evidence and ethnographic accounts of tribal and slash-and-burn "swidden" horticulture societies, it has been argued that Fort Ancient groups likely moved their villages every 10 to 30 years (Raymer 2008). This suggests that at locales featuring multiple episodes of Fort Ancient occupation (i.e., where multiple village sites have been documented), such as the Buckner site, Capitol View and Carpenter Farm, and the Florence Site Complex (Henderson 1992a; Pollack and Hockensmith 1992; Sharp and Pollack 1992; Henderson 1998), villages were not continuous or "coeval", but represented sequences of occupation and abandonment, with reoccupation occurring much later when resources replenished (Raymer 2008).

An abundance of Fort Ancient sites support the slash-and-burn farming model (Henderson 1998). Some locales clearly exhibit evidence for single, short-term occupations like the New Field site (Henderson and Pollack 1996), while others, including Carpenter Farm and the Florence Site Complex, hold evidence for multiple villages (Pollack and Hockensmith 1992; Sharp and Pollack 1992). If multiple villages are present at a single locale, they are typically temporally distinct but physically overlap slightly (Henderson 1998, 2008). At some sites with multiple villages, such as the Florence Site Complex and Fox Farm, analysis of material culture and radiometric data suggests sequential short distance moves (Sharp and Pollack 1992; Henderson 1998; Pollack and Henderson 2017).

Archaeological research has identified temporally diagnostic Middle Fort Ancient period (A.D. 1200 – 1400) artifacts such as chipped limestone discs, Type 3 Fort Ancient Coarsely Serrated Fine Triangular Projectile Points, and decorated discoidals, and defined certain attributes of projectile point and ceramic assemblages that change during this time: projectile point morphology, ceramic temper profile, exterior surface treatment, appendage form, the vessel forms present, and decoration. Together, these data can be used to aid radiometric dating in sequencing village occupation (Griffin 1943; Prufer and Shane 1970; Dunnell et al. 1971; Essenpreis 1982; Sharp and Pollack 1992; Turnbow and Henderson 1992; Henderson and Pollack 1996; Henderson 1998; Carskadden and Morton 2000; Cook 2008; Henderson 2008; Pollack et al. 2008, 2012).

In this paper, diagnostic material culture and radiometric data from the Singer-Hieronymus Site Complex in Scott County, Kentucky (Figure 2.1) are examined in attempt to build an occupational history for the site's Middle Fort Ancient component. Additionally, other datasets, such as geophysical, aerial imagery, and archaeological investigation, are utilized to provide details of the complex's spatial component (i.e., village shape, size, intensity of occupation, and internal organization).

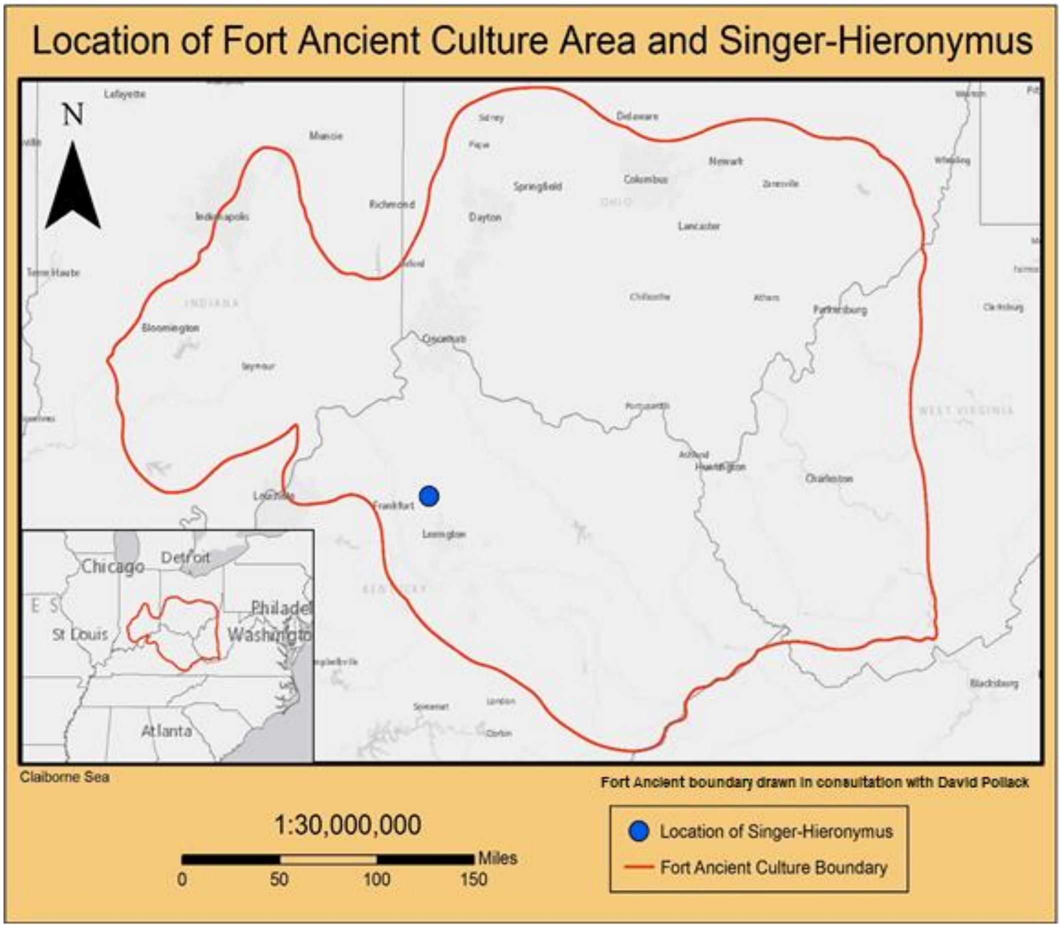


**Figure 2.1. Fort Ancient culture area before A.D. 1400 and the Location of the Singer-Hieronymus Site Complex**

<u>Background</u>

The Singer-Hieronymus Site Complex (15Sc3, 15Sc225) extends across a single NW-SE trending upland ridge in Scott County, Kentucky adjacent to a bend in North Elkhorn Creek (Figures 2.1 and 2.2). Soils on the ridge are rich in phosphate and well-drained, common for the Maury and McAfee silt loams in the Inner Bluegrass Region (Black et al. 1976). Prior investigations identified that this site complex consists of three Middle Fort Ancient villages and one early Late Fort Ancient village (Henderson 1998; Henderson and Pollack 2000).

Professional investigations at Singer-Hieronymus began in the late 1920s with the work of William S. Webb and William D. Funkhouser (Webb and Funkhouser 1928). They investigated one of two burial mounds associated with a very large circular Fort Ancient village located on the Singer property. This village, now referred to as Village C (for its speculated place in the site's occupational sequence), was the only village known at that time (Figure 2.2) (Henderson 1998). Between the 1920s and late 1990s, work at Singer-Hieronymus consisted of surface collection and mapping the surface features of Village C (Sharp and Tune 1980).

It was not until 1997 that a more intensive investigation of Village C was undertaken. Henderson (1998) placed three units within Village C. In the process, she discovered a second, smaller and less intensively occupied village slightly overlapping Village C to the northwest (now referred to as Village D). By a combination of material analysis and radiometric dating, Henderson (1998) determined that Village C was occupied sometime between A.D. 1300 and A.D. 1400, thus firmly placing it within the middle Fort Ancient period. Subsequently, Village D was determined to have been occupied sometime between A.D. 1400 and A.D. 1550, placing it in the early Late Fort Ancient period. In 1999, Kentucky Archaeological Survey personnel and volunteers from Georgetown College conducted a shovel probe survey on the Hieronymus property (Henderson and Pollack 2000). The spatial distribution of features and artifacts documented during the course of this study led to the identification of two additional middle Fort Ancient occupations (Villages A and B).

## Geophysical Survey

This investigation of Singer-Hieronymus builds upon the research conducted by Henderson and Pollack in 1999. Because neither Village A nor B had been intensively examined, geophysical survey, aerial imagery analysis, and archaeological investigations (including radiocarbon dating) were conducted to aid in determining village shape, size, and internal organization, as well as to identify archaeological features for the purpose of recovering diagnostic material and carbonized materials to determine age of occupation and to build a site occupational history of Singer-Hieronymus.

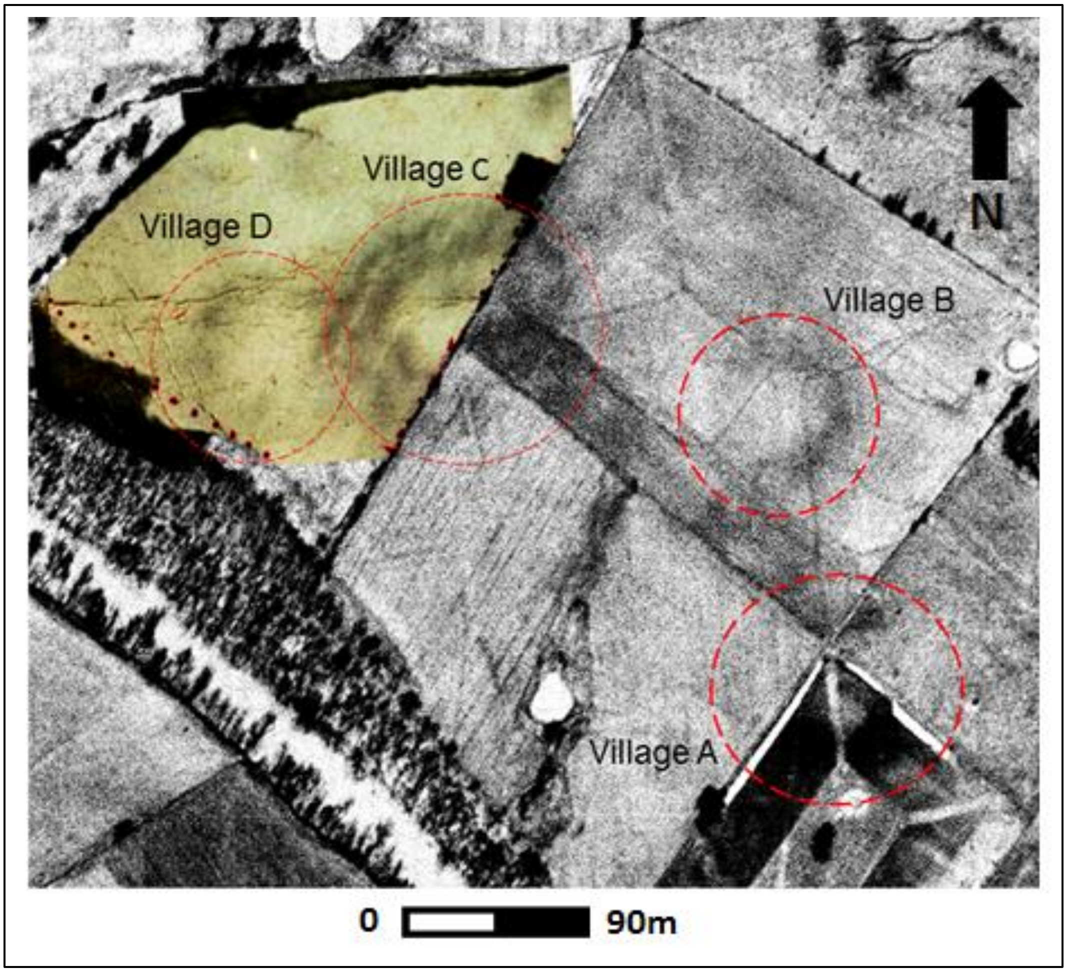


**Figure 2.2. Overlaid Historical Aerial Photographs (NRCS [late 1940s; sepia tone] and USGS [1952; grayscale]). This image shows the shape and extent of Villages A – D at Singer-Hieronymus.**

Geophysical investigations at Singer-Hieronymus began in the fall of 2016. These investigations included the use of magnetic gradiometry (MG), ground-penetrating radar (GPR), and electromagnetic induction (EMI). Targeted excavation in the summer of 2017 was based on the findings of the geophysical research. Due to a combination of deep plowing, erosion, and historic terracing, some features had been severely disturbed. Because of this, MG was much less effective than it may have been otherwise and could not aid in feature identification (Figure 2.3). Similarly, at first glance, GPR data also were less than desirable. An intensive analysis of GPR radargrams, however, revealed some pit feature profiles (Figure 2.4). In addition to feature disturbance, poor GPR results were also attributed to the differential drying of soils and pooling of water, a condition caused by impervious soil strata resulting from an agriculturally induced hardpan across the ridge on which the site is located.

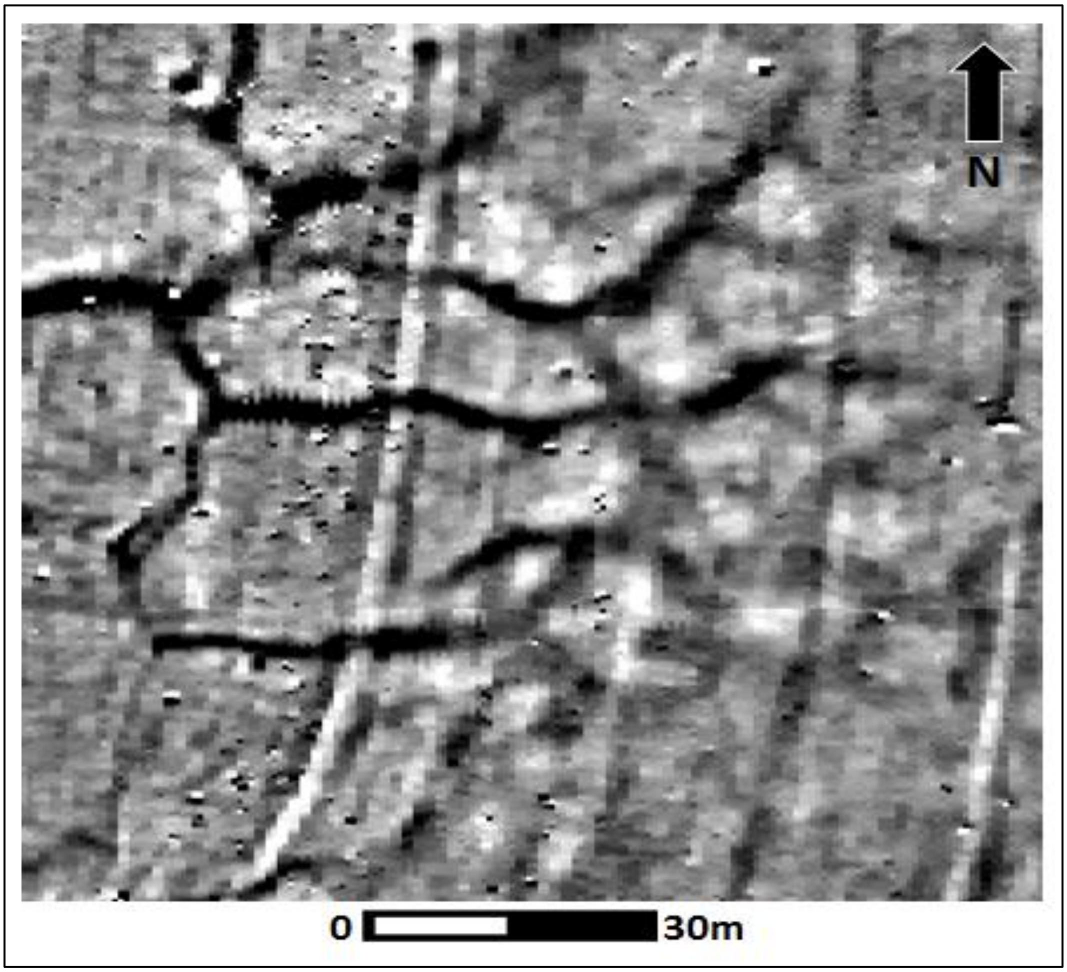


**Figure 2.3. Magnetic Gradiometry Data of Village B. The dendritic patterns represent soil erosion, and the linear patterns running north to south represent historic terraces. The dipole anomalies (black and white dots) scattered through the data represent metal and are likely trash or farming implements.**

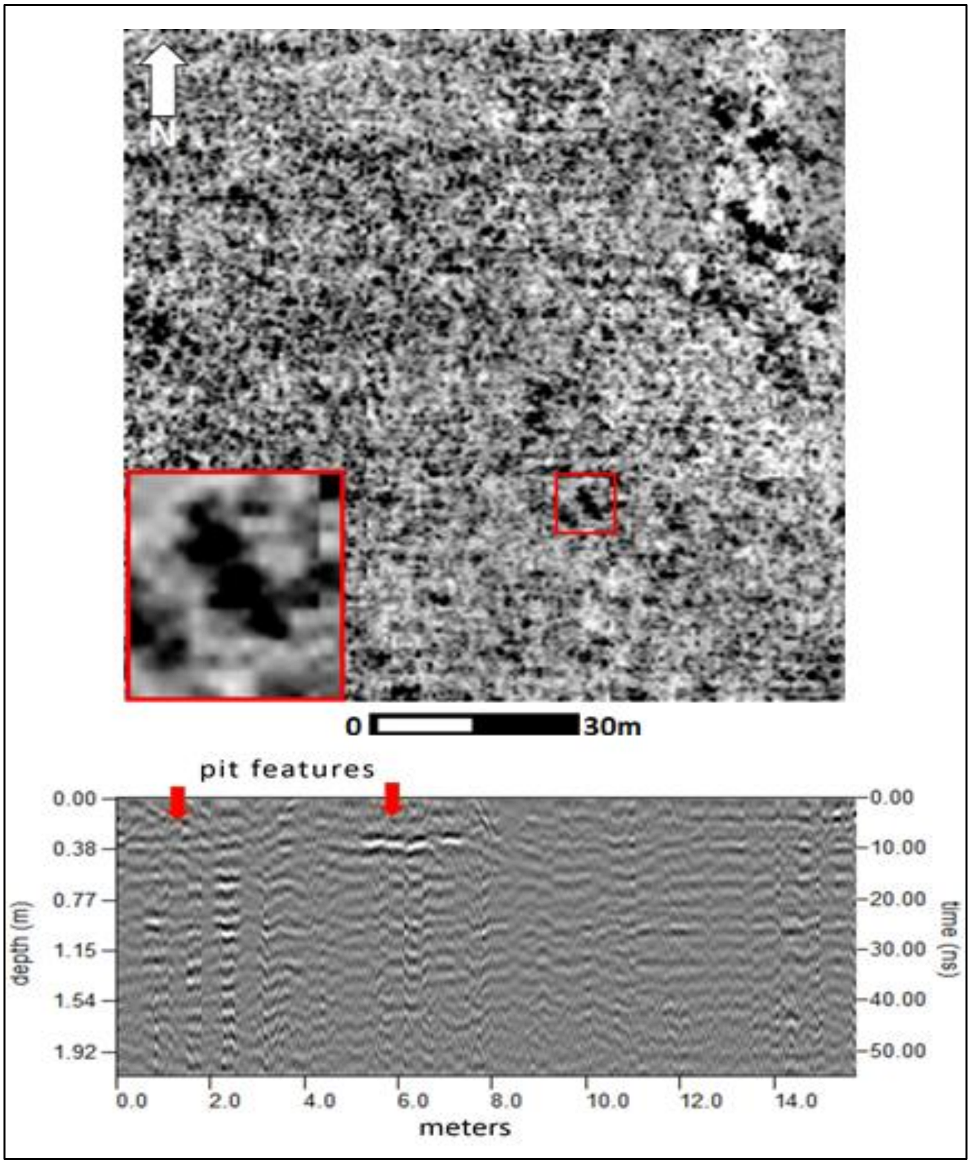


**Figure 2.4. Ground-Penetrating Radar Depth Slice at .34 m and Radargram. The depth slice (top) delineating overlapping pit features. The radargram (bottom) shows these pit features in profile.**

In contrast to MG and GPR, EMI worked very well at Singer-Hieronymus to show village refuse disposal patterns, and more specifically, areas of concentrated pit features surrounding village plazas (Figure 2.5). The identification of these areas proved that Village B was circular. Increased soil porosity, organic matter, and moisture retention, a result of human interaction with soil and waste deposition, aids in elevated apparent electrical conductivity and magnetic susceptibility (McNeil 1980; Bevan 1983; Witten 2006). It is important to note that electrical conductivity measured with EMI tends to delineate larger subsurface trends. Because refuse disposal causes a change in soil texture and chemical composition and typically occurs over a large area, EMI conductivity is optimal for defining these kinds of cultural deposits (Ernenwein 2008), even when they have been plowed through or impacted by erosion, as was the case at Singer-Hieronymus. However, because one goal of this study was to identify individual archaeological features to obtain material culture that would help build a history of Fort Ancient occupation at Singer-Hieronymus, a method for defining individual archaeological features had to be developed. This consisted of utilizing the EMI data to help identify the location of potential archaeological features within these areas in the GPR depth slices and radargrams (Figure 2.6), and then testing these data using a 2-centimeter diameter soil core to evaluate the potential features. A sample of positively identified features was then excavated to assess the geophysical data.

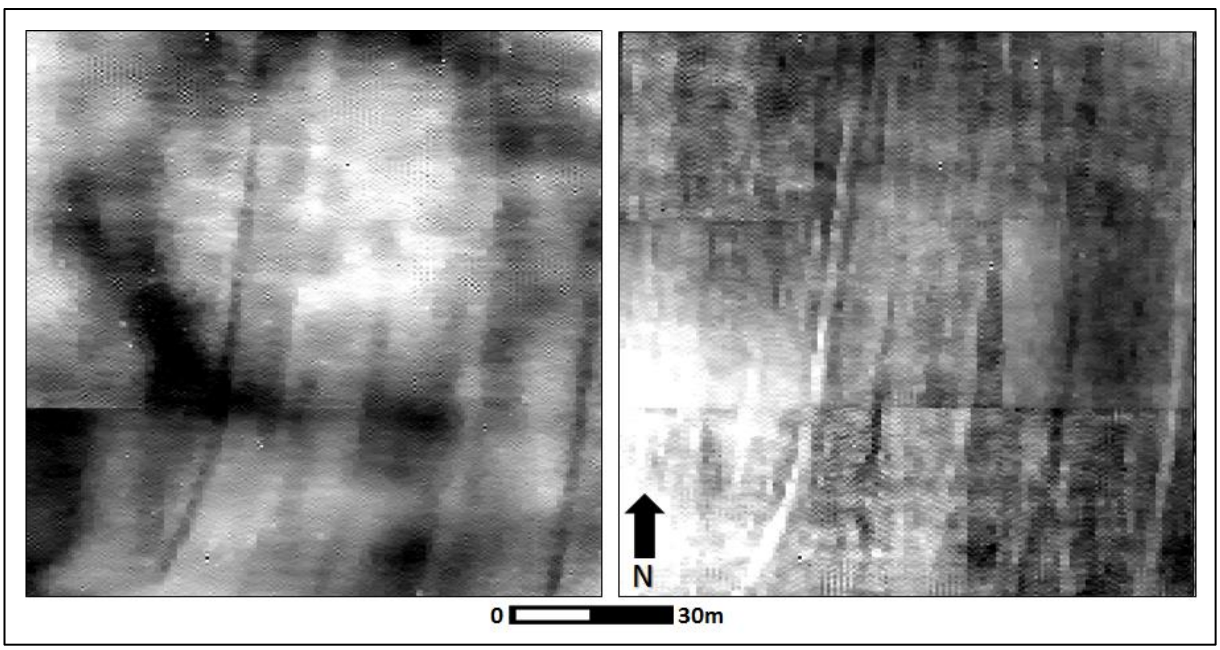


**Figure 2.5. Apparent Electrical Conductivity (left) and Apparent Magnetic Susceptibility (right) of Village B. The high conductivity (black) and magnetic susceptibility (black) represent refuse disposal on the outer edges of the village.**

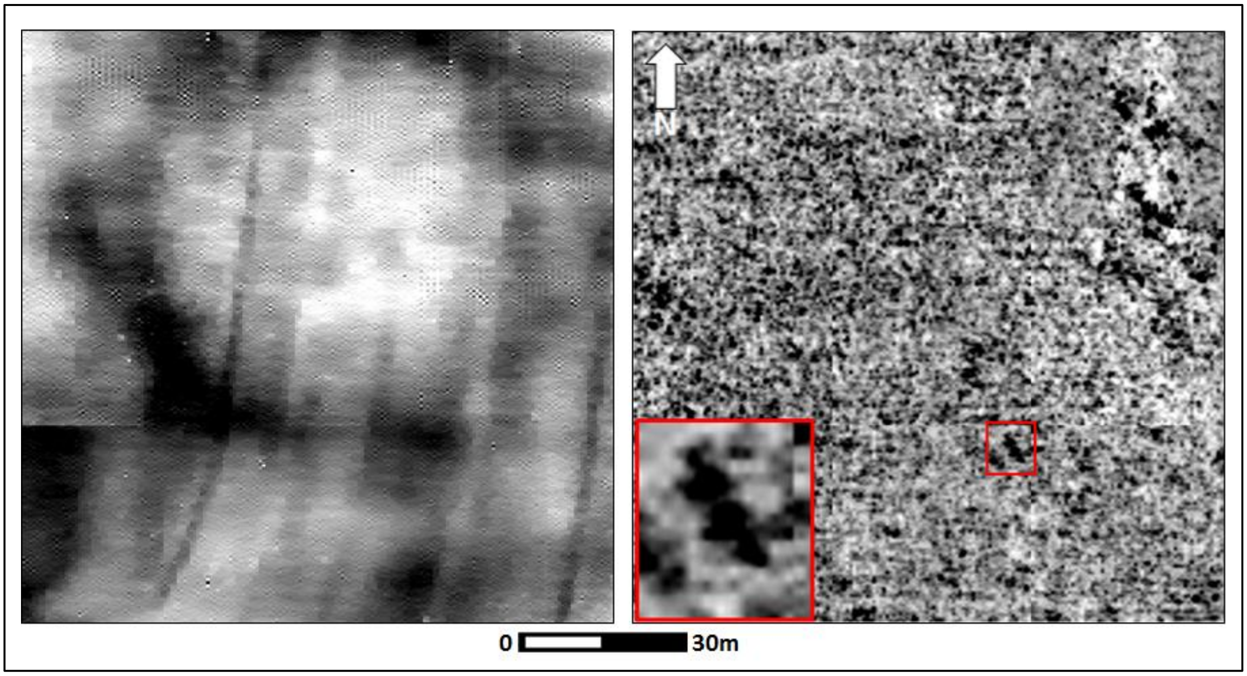


**Figure 2.6. A Representation of the Method Developed for Defining Individual Archaeological Features within the Geophysical Data. EMI data (left) are used to select potential features from the many GPR anomalies, which are then probed with a soil augur. A sampling of verified cultural features were then targeted for excavation.**

## Archaeological Excavation

Results of geophysical work and soil coring guided the targeted archaeological investigations at Singer-Hieronymus. Excavations began in May 2017 and continued for six weeks. Much of this work was conducted by the 2017 University of Kentucky undergraduate summer field school. During this time, a total of 60 square meters was excavated in Villages A, B, and C using traditional archaeological methods. This consisted of excavating a combination of 1 x 2 meter units and longer trenches to target individual features and to expose larger areas extending from the refuse deposits into the residential areas. Archaeological deposits were screened, and flotation samples were taken from each feature. Investigations documented five refuse pits, a portion of a palisade, and a house basin in Village A, nine refuse pits in Village B, and two house basins, two hearths, three refuse pits, and one infant burial in Village C.

Ten of the 17 excavated refuse pit features were identified in the geophysical investigations, however neither the structures nor the palisade were identified by the geophysical survey. With respect to the former, this was due to the fact that structure basins were either too disturbed—only the posts remained—or they were in wooded areas that couldn't be surveyed. When the palisade was encountered, only the bases of some of the postholes—very small in diameter and shallow—remained. The deeper posts had been set within or along the edges of trash pits.

## Data Analysis

Along with the data obtained from the geophysical and archaeological investigations, the artifacts recovered from each village and associated radiocarbon dates were used to temporally sequence the three midden rings (Villages A-C). The materials analyzed consisted of projectile points and ceramics, with the presence of chipped limestone discs and decorated discoidals also being noted. Certain attributes of the projectile point and ceramic material classes, including projectile point morphology and ceramic temper profile, appendage form, vessel form, and exterior surface treatment, were chosen because they have been demonstrated by other researchers to be time sensitive attributes (Prufer and Shane 1970; Dunnell et al. 1971; Essenpreis 1982; Turnbow and Henderson 1992; Henderson and Pollack 1996; Henderson 1998; Carskadden and Morton 2000; Henderson 2008; Pollack et al. 2008, 2012). Although decoration is also considered to be a good temporal marker, it was excluded in this analysis due to a small sample size.

### Village Shape, Size, and Internal Organization at Singer-Hieronymus

Prior to this research, the middle Fort Ancient midden rings at Singer-Hieronymus were interpreted to be circular (Villages A and C) or arc-shaped (Village B). However, those interpretations (particularly regarding Villages A and B) were based on limited data (Henderson and Pollack 2000). By combining historic aerial imagery analysis with the geophysical data, it is now clear that all three Middle Fort Ancient villages are circular.

These data, when placed within a GIS, were used to determine the size of each midden ring. Village B is the smallest. It measures 110 to 120 meters in diameter, with a plaza roughly 60 meters in diameter, and a 25 to 30-meter-wide domestic zone. Village A is slightly larger than Village B: 130 – 140 meters in diameter, with a plaza measures that 60 to 70 meters in diameter, and a roughly 35-meter-wide domestic zone. Village C is the largest of the Middle Fort Ancient villages at Singer-Hieronymus. This village measures 170 meters in diameter, with a plaza of roughly 80 meters in diameter, and a domestic zone that on average is 45 meters wide. Additionally, two low-earthen burial mounds—one at the southern edge of its plaza and one on the northern edge—are associated with Village C. With the exception of Village C's midden ring, all of these dimensions are consistent with those documented at other Middle Fort Ancient villages (Pollack and Hockensmith 1992; Sharp and Pollack 1992; Henderson and Pollack 1996; Henderson 1998; Cook 2008).

In addition to size and shape, data were obtained on the internal organization of the Singer-Hieronymus midden stains. Archaeological evidence provided by unit and shovel probe data contributed to this analysis. In general, all of the Middle Fort Ancient villages at Singer-Hieronymus resemble the internal organization of the Florence Site Complex: Site 15Hr22 (Sharp and Pollack 1992). Site 15Hr22 consists of a central plaza encircled by three concentric rings, each serving as a distinct activity zone. Closest to the plaza is the mortuary zone, which is surrounded by the residential zone. A trash disposal zone is located along the outer edges of the midden ring. As with Florence, within Villages A, B, and C trash disposal zones were located behind the houses. During excavation, no burials were encountered between residential and trash disposal zones. The 1999 shovel probe survey located one burial between the plaza and the recently defined residential zone in Village C. Therefore, it was inferred that mortuary zones were located between the houses and the plazas as at the Florence Site Complex (Sharp and Pollack 1992) and Sun Watch Village in Ohio (Cook 2008). However, this remains to be verified.

To assist in the temporal ordering of the three villages, five charcoal samples were submitted for radiometric dating. These dates, combined with those obtained by Henderson (1998), provide a more robust chronometric sample for the site complex (Table 2.1). Surprisingly, all of the radiocarbon dates were very tightly spaced. An examination of the dates suggests that each of the Middle Fort Ancient villages at Singer-Hieronymus were occupied within a 125-year timespan (A.D. 1275 – 1400). To verify this, attributes of the projectile point and ceramic assemblages from each midden were examined to identify material cultural differences that could be used to sequence the three villages. The presence of chipped limestone discs and decorated discoidals also were noted.

**Table 2.1. Chronometric Dates**

| Component | Age (B.P.) | Calibrated Date[2] (2-sigma) | Median Calibrated Date |
|---|---|---|---|
| **Village A** | | | |
| [2]OS – 133988 | 705 ± 20 | 1266-1298 (98%) 1372-1377 (42%) | **1282** |
| [2]OS – 138560 | 650 ± 15 | 1286 – 1314 (42%), 1356 – 1388 (58%) | **1372** |
| **Village B** | | | |
| [2]OS – 138528 | 625 ± 20 | 1292 – 1328 (39%), 1341 – 1396 (61%) | **1369** |
| [2]OS – 138561 | 650 ± 15 | 1286 – 1314 (42%), 1356 – 1388 (58%) | **1334** |
| **Village C** | | | |
| [1]Beta – 114185 | 700 ± 60 | 1219 – 1333 (68%), 1336 – 1398 (32%) | **1295** |
| [1]Beta – 114186 | 670 ± 70 | 1224 – 1235 (2%), 1241 – 1413 (98%) | **1322** |
| [1]Beta – 114187 | 640 ± 70 | 1262-1423 (100%) | **1342** |
| [2]OS – 133527 | 665 ± 15 | 1282 – 1307 (56%), 1362 – 1385 (44%) | **1295** |
| **Village D** | | | |
| [1]Beta – 114188 | 360 ± 60 | 1443 – 1645 (100%) | **1544** |
| [1]Beta dates obtained from Henderson 1998; [2]OS dates were processed by Woods Hole Oceanographic Institute in 2018; All dates were calibrated using Calib Version 7.1 | | | |

<u>Material Culture: Stone Artifacts</u>

Jimmy A. Railey (1992) first developed a Fort Ancient fine triangular projectile point typology. In his study of exclusively northeastern Kentucky Fort Ancient fine triangular points, he identified six types. Over time, modifications have been made to Railey's typology, given the availability of new data from Fort Ancient sites in Kentucky and Ohio (Henderson 1998; Pollack and Henderson 2000; Henderson 2008; Pollack et al. 2012; Cook and Comstock 2014). Henderson (1998) introduced two new variants adding Types 2.1 and 3.1 to the typology. Pollack et al. (2012) identified temporal trends in the popularity of certain point types particularly common to the Middle Fort Ancient period such as Types 2, 3, and 5. It was noted that Type 2 points occur consistently throughout the Early and Middle Fort Ancient periods (A.D. 1000 – 1400) but decrease in popularity relative to Type 5 points. Type 3 points are strictly diagnostic of the Middle Fort Ancient period, and reached their peak of popularity in the 1300s, at sites such as Fox Farm, Florence, and Singer-Hieronymus (Pollack and Henderson 2017).

The triangular point assemblages from all villages were comprised primarily of Types 2 and 5, with Type 3 points also being present. It was hypothesized that by noting the ratio of Types 2 to 5, given the temporal trends defined by Pollack et al. (2012), the villages could be better situated within the Middle Fort Ancient period, or perhaps a better understanding of the Middle Fort Ancient sequence of occupation at Singer-Hieronymus could be obtained. Because of limited sample size from good contexts, points could not be used reliably to aid in sequencing the villages.

While the presence of chipped limestone discs was noted in the assemblages of each of the Middle Fort Ancient villages at Singer-Hieronymus, their presence only indicates Fort Ancient occupation sometime during the Middle Fort Ancient period (A.D. 1200 – 1400). The presence of Fort Ancient Type 3 Coarsely Serrated Fine Triangular Projectile Points and decorated discoidals, however, points to some degree of contemporaneity with the late Middle Fort Ancient (A.D. 1300-1400) Fox Farm site (Pollack and Henderson 2017).

**Table 2.2. Frequency of Fort Ancient Fine Triangular Projectile Point Types by Village**

| Point Type | Village A | Village B | Village C |
|---|---|---|---|
| Type 2 | 1 | 1 | 4 (9) |
| Type 2.1 | 0 | 0 | 0 (3) |
| Type 3 | 1 | 1 | 0 (5) |
| Type 3.1 | 0 | 0 | 0 (2) |
| Type 5 | 4 | 0 | 3 (7) |
| Numbers in parentheses were obtained from Henderson 1998 and Pollack et al. 2012 Table 1. | | | |

Material Culture: Ceramic Artifacts

The analyzed ceramic assemblage recovered from the three midden rings during the 2017 field season (n = 1,857) consisted of body sherds larger than 4 cm², rims, handles, and decorated sherds. Of the 1,857 sherds analyzed, 346 were recovered from Village A, 105 from Village B, and 1,406 from Village C. The information presented here concerns only those attributes that have been determined by prior research to be temporally diagnostic (Turnbow and Henderson 1992; Henderson 1998; Pollack et al. 2008; Sea 2015): temper profile, surface treatment, appendage form, and vessel form. While decoration is considered a temporally diagnostic ceramic attribute, because of small sample size, it was recorded but not included in the intervillage comparative analysis.

Middle Fort Ancient ceramic traditions vary regionally (Griffin 1943; Prufer and Shane 1970; Dunnell et al. 1971; Essenpreis 1982; Turnbow and Henderson 1992; Henderson 1998; Carskadden and Morton 2000). In central Kentucky, the predominant Middle Fort Ancient period ceramic series is the Jessamine Series (Sharp 1990; Sharp and Pollack 1992; Henderson 1998). As expected, ceramic materials recovered from Singer-Hieronymus are primarily of the Jessamine Series. Nearly three-quarters of all sherds were exclusively shell tempered. Exclusively limestone tempered examples represented less than five percent of sherds. The remainder exhibited a mixture of shell and limestone temper (Table 2.3).

In central Kentucky, exterior surface treatment trends toward plain by the late Middle Fort Ancient period (Sharp 1990). In total, 1,809 sherds presented identifiable surface treatment within the

Singer-Hieronymus assemblage. As expected, two major types of exterior surface treatment were identified: plain and cordmarked. One minor surface treatment also was identified: knot-roughened. When examining the assemblages of each village individually, Villages B and C contained more cordmarking—this surface treatment represented 59% of their assemblages, respectively. In contrast, plain pottery accounts for 71% of the Village A assemblage. Knot-roughening occurred in very low quantities in the assemblages of both Village A and Village C (Table 2.3). Based on exterior surface treatment, Villages B and C could be earlier than Village A.

The presence or absence of certain vessel forms is also a temporal marker. In Fort Ancient ceramic assemblages, early in the middle Fort Ancient period, assemblages consist primarily, if not exclusively, of jars. By the late Middle Fort Ancient period, bowls and pans begin to make appearances in site assemblages. During the Late Fort Ancient period, bowls and pans are very common vessel forms (Turnbow and Henderson 1992).

**Table 2.3. Temporally Diagnostic Ceramic Data**

| Attribute | Village A | Village B | Village C |
|---|---|---|---|
| **Temper** | | | |
| Shell | 74% | 73% | 72% |
| Limestone and Shell | 25% | 23% | 23% |
| Limestone | 1% | 4% | 5% |
| **Surfae Treatment** | | | |
| Plain | 71% | 41% | 39% |
| Cord-Marked | 6% | 22% | 22% |
| Smoothed-Over Cord-Marked | 23% | 37% | 37% |
| Knot-Roughened | 1% | 0% | 2% |
| **Vessel Form** | | | |
| Jar | **X** | **X** | **X** |
| Bowl | **-** | **X** | **X** |
| Pan | **-** | **-** | **X** |
| **Appendage Style** | | | |
| Loop/Strap | **-** | **X** | **-** |
| Wide, Thin Convergent-Sided Strap | **X** | **-** | **X** |
| Thick Parallel-Sided Strap | **X** | **X** | **X** |
| Non-Handle Appendage | **X** | **X** | **X** |

From Villages A and B, two vessel forms were identified: jars and bowls. Village A's assemblage is comprised of jars. Similarly, jars comprise almost the entire assemblage of identifiable vessels from Village B, however, bowl fragments were identified in the Village B assemblage. Both vessel forms were identified in the Village C assemblage.  Thus, based on absence of bowls, one could infer that Village A was occupied slightly earlier than Villages B and C.

Middle Fort Ancient appendage styles are time sensitive ceramic markers as well. Handle styles transition in form from predominantly loop handles in the early Middle Fort Ancient period to loop/strap, thick convergent-sided strap handles, and eventually wide, thin, parallel-sided strap handles by the late Middle Fort Ancient period (Turnbow and Henderson 1992; Henderson 2008). Non-handle appendages, such as lugs, nodes, rim strips, and effigies, tend to be more spatially sensitive than time sensitive during the Middle Fort Ancient period (Prufer and Shane 1970; Essenpries 1982; Carskadden and Morton 2000; Sea 2015).

Village A, B, and C assemblages contained thick parallel-sided strap handles, and Villages A and C also contained wide, thin, convergent-sided strap handles (Table 2.3). Non-handle appendage forms were also recovered from Singer-Hieronymus. These consisted of double-vertical and semicircular lugs commonly seen in ceramic assemblages from the Fox Farm site in northern Kentucky and the Baum site in central Ohio (Prufer and Shane 1970; Sea 2015).

Because of significant overlap in ceramic attributes, none could be used to distinguish one village from the other. Although ceramic attributes cannot be used to effective order the three midden rings, as with the Type 3 projectile points, they do point to some level of interaction with the contemporary Fox Farm site. Decorated rimfolds, punctuation both on jar rims and as fill inside jar neck decorative motifs, knot-roughened jar exterior surface treatment, and non-handle appendages are uncharacteristic of the Jessamine series, but are characteristic of Fox Farm ceramics (Griffin 1943; Sea 2015; Pollack and Henderson 2017). Additionally, decorated rimfolds are characteristic of Anderson series ceramics (Essenpreis 1982). The presence of fabric impressed pans represents interaction with Mississippian communities to the south and west of the Fort Ancient culture area (Pollack 2008).

## Conclusion

The objective of this study was to create a history of the Middle Fort Ancient occupation of the Singer-Hieronymus Site Complex by sequencing the occupation of the three midden rings. Building upon previous research, a combination of geophysical survey and aerial imagery was used to determine the size and shape of Villages A and B, neither of which had been intensively investigated before. This study also refined the size and shape of Village C, a previously investigated village. It was concluded that all villages were circular in shape, and while Villages A and B were similar in size, Village C was somewhat bigger, inferring a larger population.

Geophysical survey also was used to identify archaeological features to target for excavation, with the goal of obtaining diagnostic material culture and radiometric data from each village. An examination of village size, shape, and organization, as well as diagnostic materials and chronometric data, suggest that during late Middle Fort Ancient times, the Singer-Hieronymus Site Complex was continuously occupied. Villages A, B, and C each produced materials representative of the late Middle Fort Ancient (A.D. 1300-1400), including predominately shell tempered vessels, wide, thin, convergent-sided strap handles, and the presence of bowls and pans. In addition, the use of punctation as decorative fill, knot roughening as a surface treatment, and the presence of Type 3 Fine Triangular projectile points and decorated discoidals, reflect some degree of contemporaneity and interaction with Fox Farm's late Middle Fort Ancient occupation. Similarly, the recovery of Anderson-like decorated rimfolds reflects some level of interaction with Fort Ancient groups living in northern Kentucky/southwestern Indiana.

The overall similarity of the material culture recovered from Villages A, B, and C, and the radiocarbon dates obtained from each village is suggestive of short distance, micro-moves of a single village on the immediate landscape, without a hiatus in site occupation. Since Singer-Hieronymus appears to have been continuously occupied for at least 100 years, it does not conform to the standard model of Fort Ancient slash-and-burn agriculture that is supposed to result in village abandonment every 10 to 30 years. As with Fox Farm, the data from Singer-Hieronymus suggest that environmental degradation was not always a determining factor in site abandonment. With this in mind, as suggested by Pollack and Henderson in 1992, social factors, such as population stress and factionalism, may have contributed to site abandonment. Future research at Singer-Hieronymus will examine the extent to which the power of place and social identity contributed to village longevity.

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CHAPTER 3

# LANDSCAPE-SCALE ELECTROMAGNETIC INDUCTION SURVEY AS A PRIMARY APPROACH FOR SITE RECONAISSANCE

Claiborne Daniel Sea and Eileen Gloria Ernenwein


## Abstract

In recent decades, much of the development in geophysical instrumentation has benefited by innovations in computing.  As computing power continues to strengthen, the collection, processing, and storing of very large, high-resolution geophysical datasets will become increasingly accessible to archaeologists.  This accessibility broadens the scale of possible research questions, and the variety of geophysical approaches in terms of instrumentation and survey method that are available for archaeological purposes. Some geophysical approaches are underutilized in archaeology. One approach that has witnessed underutilization, and consequently, the slowing of methodological development is electromagnetic induction (EMI) survey. EMI is a near-surface geophysical approach that utilizes time-varying electromagnetic fields to simultaneously measure apparent magnetic susceptibility and apparent electrical conductivity. Following a preliminary geophysical survey using magnetic gradiometry, ground-penetrating radar, and EMI, a landscape-scale EMI survey was conducted with great success at the Singer-Hieronymus Site in central Kentucky, USA. In conjunction, apparent electrical conductivity and magnetic susceptibility identified the locations of all known villages at the site and three potentially new villages. This study draws attention to the applicability of landscape-scale EMI survey using Singer-Hieronymus as an example and advocates a reconsideration for the use of EMI survey as a first approach when conducting geophysical reconnaissance on archaeological sites worldwide.

## Introduction

Four geophysical methods are commonly used worldwide for archaeological prospection: magnetic gradiometry (MG), electrical resistance (ER), ground-penetrating radar (GPR), and electromagnetic induction (EMI). For decades it was common to choose a single method in order to save on the initial equipment investment and efficiently negotiate the learning curve (Clay 2001). As instruments improved and it became clear that the success of each geophysical approach varies greatly from site to site, archaeologists realized the value of employing a spectrum of geophysical methods (Clay 2001; Toom and Kvamme 2002; Kvamme 2003; Henry et al. 2014). It is still very common, however, to choose only one or two methods deemed most efficient and effective—chiefly MG paired with either ER or GPR. Repeated success of these methods, particularly MG, has fueled vast improvements to data quality and survey efficiency.

Despite widespread success of MG, ER, and GPR, cases exist where these approaches have not been effective in identifying archaeological signatures. When this happens, most researchers conclude that the site is not conducive for geophysics and in many cases turn to intrusive forms of investigation. In a high-stakes environment such as Cultural Resource Management (CRM) archaeology in North America, for example, if MG alone isn't conclusive, it may be determined that there are no potential features to be investigated. This poses a risk to the conservation, preservation, and sustainability of archaeological resources. Here we make the case that EMI should be seriously considered alongside the other methods, and in some cases should be the first choice. Several hectares of high density (0.25-1.5 m point spacing) data can be collected per day using motorized transport integrating global navigation satellite systems (GNSS), and a range of features having electrical or magnetic contrast can be detected at multiple depths.

EMI utilizes time-varying electromagnetic fields to simultaneously measure apparent electrical conductivity ($EC_a$) and apparent magnetic susceptibility ($MS_a$) at multiple depths (Witten 2006; Ernenwein 2018). $EC_a$ is the theoretical inverse of ER, but the fact that EMI measures by induction, versus probe insertion for ER, means that the results can be quite different. Typically, ER outperforms

$EC_a$ for detection of highly resistive targets such as rock walls, while $EC_a$ outperforms ER for mapping broad conductive bodies. $EC_a$ is well-suited for detecting moats and ditches (Kvamme 2003; De Smedt et al 2013; Saey 2013; Saey 2014), earthworks (Dalan 1991; Clay 2001a; Clay 2001b), middens (Ernenwein 2008), and other large accumulations of conductive material. In some cases, it provides geoarchaeological context, such as the location of ancient river channels, now buried (Conyers et al. 2008; De Smedt et al 2011). $EC_a$ can also detect discrete archaeological features, including structures (Kvamme 2003; Simpson et al. 2009; Lockhart 2010; De Clercq et al. 2012; Welham et al. 2014; Wiewel and Kvamme 2016) ancient roads (Thiesson et al. 2009; Mozzi et al. 2016), and historic water and sewer lines (Kvamme 2006).

$MS_a$ is theoretically related to MG, which is sensitive to both induced and remanent magnetic fields, but the two datasets are markedly different. The commonly used gradient configuration for MG (e.g. fluxgate and cesium gradiometer configurations) records only residual measurements, often filtering out broad, subtle features. Total field magnetometry configurations avoid this problem but are rarely used. MG is sensitive to greater depths but produces dipolar anomalies that are sometimes more ambiguous than $MS_a$ anomalies from the same features (Dalan 2008; Simpson et al. 2009). $MS_a$ has been shown to detect more subtle and discrete features when they are relatively shallow (Ernenwein 2008; Lockhart 2010; Klehm & Ernenwein 2016).

Despite its broad applicability for archaeology, EMI is used less frequently and lags in technological innovation when compared to MG, ER, and GPR (Gaffney 2008; Reynolds 2011). The more a method is used, the more it becomes streamlined for efficient survey, which in turn promotes wider use. The growing use of multisensor carts with GNSS integration make geophysical survey faster, but at present this is only commonly practiced worldwide with commercially available MG carts (David et al. 2008; Campana and Dabas 2011) and with ER using the Automatic Resistivity Profiler (ARP © Geocarta), mainly in Europe (Dabas 2008; Campana et al. 2009). More recently, GNSS-enabled array systems have vastly improved GPR survey speed and resolution (Linford et al., 2010; Trinks et al., 2010; Novo et al., 2012), though their widespread use is limited by high cost and difficulty transporting the rather large, heavy equipment long distances. EMI has not yet been optimized for archaeological survey, and there are no commercially available multisensor cart systems. Several recent case studies (Simpson et al. 2009; Simpson et al. 2009; Thiesson et al. 2009; De Smedt et al. 2013; Saey et al. 2013; De Smedt et al 2014; Mozzi et al. 2016; Dabas et al. 2016), all in Europe, show innovations toward vehicle-towed systems. Ironically, EMI survey was once noted as a "fast" geophysical approach (Clay 2006). Indeed, when using traditional approaches, i.e. single sensors carried on foot without GNSS integration, EMI survey is slower than MG but roughly on par with GPR and ER, depending on survey strategy. The potential for rapid survey and the richness of information gathered makes EMI an equally valuable approach.

EMI may be slow to be adapted because of its reputation for failing to delineate discrete archaeological features, and its tendency to drift, making data processing more technically challenging. EMI is generally known for its ability to measure $EC_a$; most likely because this is what the technology was originally invented for (McNeill 1980; Ernenwein 2018). Indeed, commonly used instruments made by Geonics Limited (Mississauga, Ontario) are still marketed as "conductivity meters" (e.g. the EM38- and EM31- series). $EC_a$ results, when compared to MG, ER, and GPR, often show broad patterns rather than discrete archaeological features (Ernenwein 2008; Kvamme et al. 2018). In some cases, however, discrete features are mapped with $EC_a$ (Kvamme 2003, 2006; Simpson et al. 2009; Thiesson et al. 2009; Lockhart 2010; De Clercq et al. 2012; Welham et al. 2014; Mozzi et al. 2016; Wiewel and Kvamme 2016). We argue that $EC_a$ data that show broad patterns are also extremely useful, especially when used in parallel with other geophysical methods such as MG, ER, and GPR, which rarely detect broad patterns.

Less widely known is that $MS_a$ data usually show discrete features, often with equal or greater clarity than MG data, even when $EC_a$ does not (Ernenwein 2008; Klehm & Ernenwein 2016; Kvamme et al. 2018). Use of $MS_a$ data is overlooked or deemed unsuitable because of its more limited depth penetration and tendency to drift much more than the $EC_a$ measurements. Depth penetration will remain a limitation for some archaeological sites, but drift is much less of a problem because it can be removed with data processing as shown by Delefortrie et al. (2014) and in this paper. As EMI grows in popularity it will become clear that both $EC_a$ and $MS_a$ components are useful for archaeology and the ability to simultaneously collect these data, often at multiple depths (when using multi-receiver Slingram instruments such as the EM38MK2 or Dualem21-S), makes this method a top choice for large-area, reconnaissance surveys.

It is worth repeating that not all geophysical methods are effective in all environments or sites, and that a full range of methods should be employed (Kvamme 2003), especially in those cases where MG and ER or GPR aren't conclusive. Each method has strengths and weaknesses in terms of sensitivity to different properties and depths. In this study, MG, GPR, and EMI were all used to investigate the Singer-Hieronymus Site in Kentucky, USA. A small (90 x 90 m), preliminary survey was conducted to determine which methods provided useful information about buried archaeological deposits given local conditions. EMI gave the best results, so the survey was expanded to cover a much larger area. Data collection and processing procedures were modeled after European approaches to landscape-scale EMI survey (De Smedt et. al 2013, Delefortrie et al. 2014; De Smedt et al. 2014, and 2016), but modified to detect smaller, more subtle features typical at prehistoric sites in North America. This study illustrates that this method of deploying EMI should be considered as a first approach for geophysical prospection, as it revealed the most about the layout of this large, multi-village site.

## Electromagnetic Induction Theory of Operation

Electromagnetic induction (EMI) is a near-surface geophysical approach that utilizes time-varying electromagnetic fields to simultaneously measure apparent magnetic susceptibility (MSa) and apparent electrical conductivity ($EC_a$) (Witten 2006; Ernenwein 2018). Various EMI systems are used in geology and other disciplines, but archaeology is best approached using the Slingram method (Scollar at al. 1990); other types of EMI are not included in this paper. Figure 3.1 illustrates the induction process. When a time-varying electrical current is applied to a coil of wire, it creates a time-varying electromagnetic (EM) field. This EM field, known as the primary field, then creates electrical currents called eddy currents in the materials through which they pass. Eddie currents produce a secondary EM field that is proportional to the electrical and magnetic properties of buried objects and surrounding soils. $MS_a$ and $EC_a$ are then measured by another coil of wire at a fixed distance from the transmitting coil (McNeill 1980; Bevan 1983; Witten 2006; Ernenwein 2018).

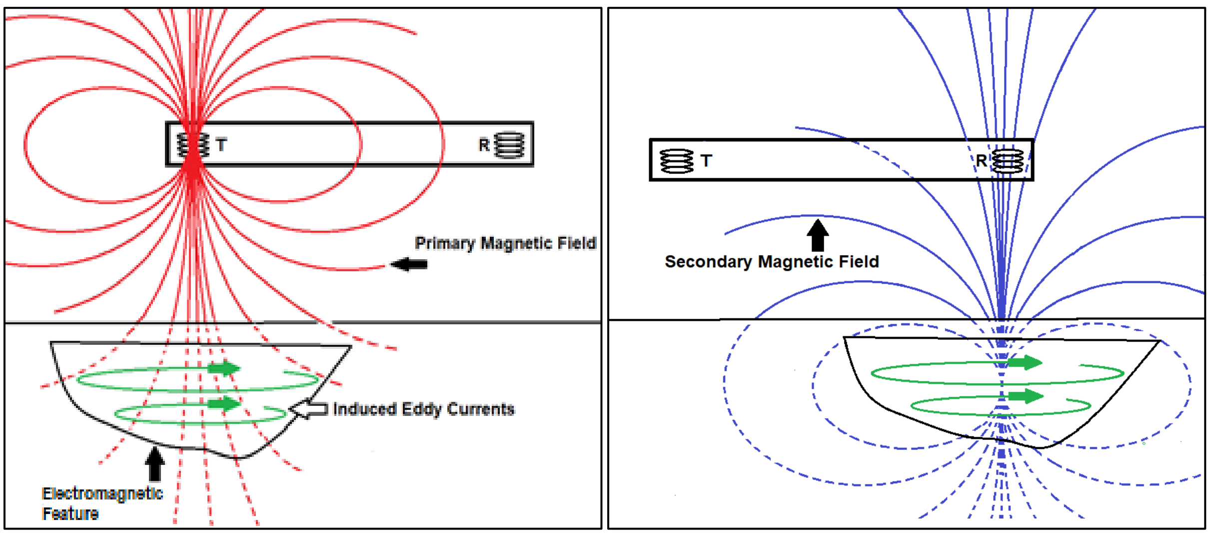


**Figure 3.1. Electromagnetic Induction Theory of Operation. Slingram electromagnetic induction works by the transmission of a primary magnetic field from the transmitter coil (T), which induces eddy currents in electromagnetic features (left), and in turn produces a secondary field that is ultimately measured by the receiver coil (R) (right).**

EMI depth penetration is dictated by the transmitted frequency and corresponding distance between transmitter and receiver coils. Lower frequencies are paired with wider coil spacing for greater depth penetration (McNeill 1980). In addition, $EC_a$ can be measured to more than twice the depth as $MS_a$. Two ways of describing depth are important for understanding the results presented in this paper: maximum or "effective" depth and the depth of peak signal response. Both are influenced by energy loss known as attenuation. Effective depth refers to the maximum depth at which subsurface deposits significantly contribute to the secondary magnetic field (McNeill 1980; Witten 2006). Peak response refers to the depth at which induced currents in subsurface deposits provide maximum contribution to the secondary magnetic field (Figure 3.2) (McNeill 1980). For example, the primary EM field transmitted by the instrument will possess an amount of energy proportional to the energy used to produce it. As the primary magnetic field enters the ground, energy will be lost to the creation of localized induced currents within the soil and buried objects. At a point, subsurface deposits will contribute the highest energy per depth to the secondary magnetic field before decreasing exponentially. This is peak EMI signal response. As the magnetic field penetrates deeper, it will lose energy to attenuation until it is depleted (figure 3.2). Because contributions to the secondary magnetic field after 75% signal energy loss are deemed insignificant, the depth to which 75% of signal energy is lost is considered the effective depth (McNeill 1980; Witten 2006; Ernenwein 2018).

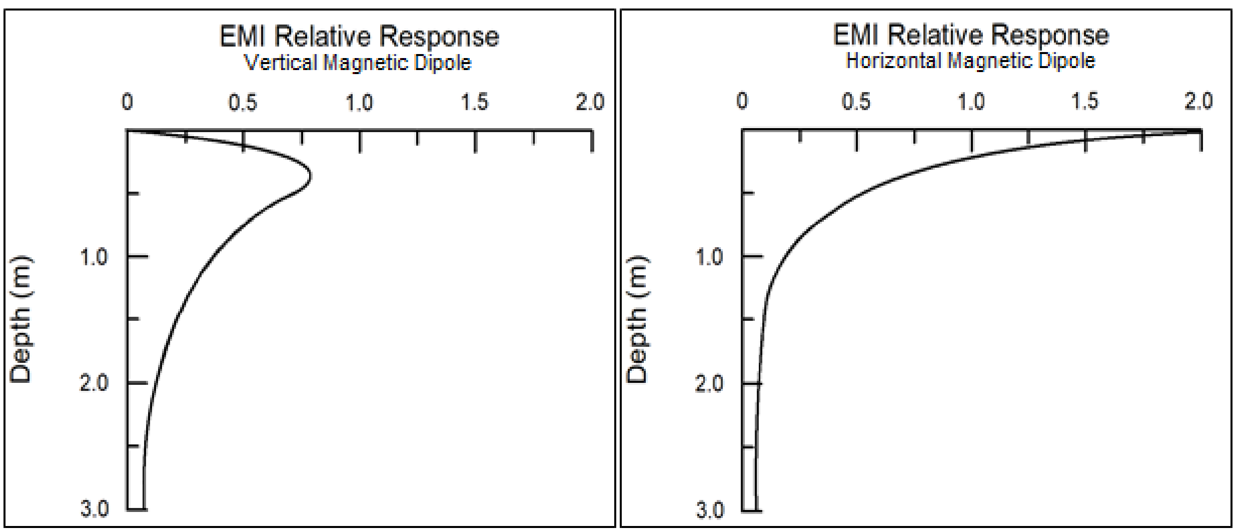


**Figure 3.2. Relative Conductivity Responses for Vertical (left) and Horizontal (right) Magnetic Dipoles Spaced 1.0 m Apart as a Function of Depth. Vertical Relative Response: $\boldsymbol{\phi_V(z) = (4z)(4z^2+1)^{3/2}}$. Horizontal Relative Response: $\boldsymbol{\phi_H(z) = 2-(4z)(4z^2+1)^{1/2}}$.**

For this study, an EM38-MK2 Ground Conductivity Meter (manufactured by Geonics Limited, Canada) was used. This instrument simultaneously measures $MS_a$ in parts per thousand (ppt) and $EC_a$ in millisiemens per meter (mS/m). It features one transmitter coil operating at 14.5 kHz and parallel receiver coils at fixed distances of 0.50 and 1.0 m. Like many EMI instruments, the EM38-MK2 can survey with its coils oriented horizontally, producing vertical magnetic dipole for maximum depth penetration. This is known as the vertical dipole mode (VDM), and is illustrated in Figure 3.1. The instrument can also be turned on its side so that its coils are oriented vertically, producing a horizontal magnetic dipole—the horizontal dipole mode (HDM) (McNeill 1980). When in VDM, the EM38-MK2 can reach a maximum depth of 1.5 m and peak relative response of .40 m at a 1.0 m coil spacing when measuring $EC_a$. These depths are halved when measuring $EC_a$ at a coil separation of 0.50 m. When measuring $MS_a$ in VDM, at a 1.0 m coil separation, the instrument has a maximum depth penetration of 0.50 m with a peak relative response of 0.25 m. Again, these depths are halved when measuring $MS_a$ at a coil spacing of 0.50 m. When measuring $EC_a$ in HDM, at a 1.0 m coil separation maximum depth penetration is 0.75 m with a peak relative response at the ground surface. At a coil spacing of 0.50 m, maximum depth of exploration is halved andthe peak EMI response is still at the ground surface. When measuring $MS_a$ in HDM at 1.0 m coil separation, the instrument has a maximum depth penetration of 0.60 m, with a peak relative response of 0.30 m. These depths are halved when measuring $MS_a$ in HDM with a coil separation of 0.50 m (Table 3.1).

**Table 3.1. Peak Response and Maximum Depths of the EM38-MK2 in VDM and HDM at both 1.0 m and 0.50 m Coil Separation**

| **Depth** | **Vertical Dipole Mode (VDM)** | | | | **Horizontal Dipole Mode (HDM)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **1.0 m $EC_a$** | **0.5 m $EC_a$** | **1.0 m $MS_a$** | **0.5 m $MS_a$** | **1.0 m $EC_a$** | **0.5 m $EC_a$** | **1.0 m $MS_a$** | **0.5 m $MS_a$** |
| Peak Response | 0.40 m | 0.20 m | 0.25 m | 0.12 m | n/a | n/a | 0.30 m | 0.15 m |
| Maximum | 1.5 m | 0.75 m | 0.75 m | 0.50 m | 0.75 m | 0.37 m | 0.60 m | 0.30 m |

<u>The Singer-Hieronymus Site Complex</u>

The Singer-Hieronymus Site is a complex of at least four separate circular Fort Ancient villages covering 12 ha of an 18-ha ridgetop in central Kentucky, eastern USA. The Fort Ancient were a Native American tribal society that lived in central, northern, and eastern Kentucky, southern Ohio, southeastern

Indiana, and western West Virginia from roughly A.D. 1000 – 1750 (Henderson 1998) (Figure 3.3). Material culture analysis and radiocarbon dating of each of the four confirmed villages indicates that Singer-Hieronymus was occupied, perhaps continuously, from roughly A.D. 1300 – 1550 (Henderson 1998). Soil characteristics on the ridge include silt loams of the Maury and McAfee Series. These silt loams are common in central Kentucky and are typically underlain by members of the phosphatic Lexington Limestone Formation. Silts in both series are well drained, contain medium to high levels of phosphate, and can range from neutral to acidic (Black et al. 1976).

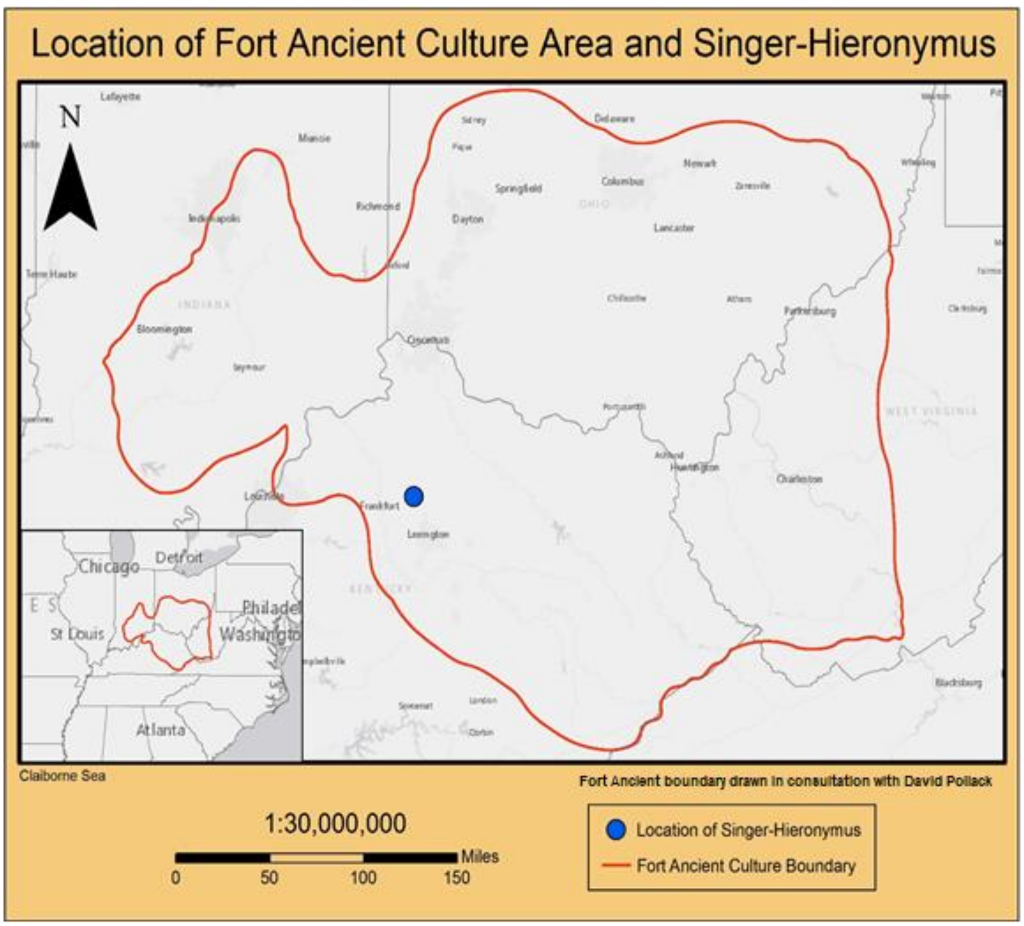


**Figure 3.3. Extent of the Fort Ancient Cultural Boundary and General Location of the Singer-Hieronymus Site Complex**

Professional assessment of the site began in the 1920s, when University of Kentucky archaeologists William S. Webb and William D. Funkhouser investigated one of two burial mounds associated with the only village known to comprise the Singer-Hieronymus Site at that time (Webb and Funkhouser 1928). This village is now referred to as Village C for its proposed sequence in the occupational history of the site. From the 1920s until the late 1990s, work at Singer-Hieronymus primarily consisted of surface collecting and mapping landscape features of Village C.

It was not until the late 1990s that a more systematic investigation of Village C and adjacent private properties was undertaken. As part of her dissertation research, A. Gwynn Henderson placed three test units within Village C. By analyzing a National Resources Conservation Service (NRCS) historic aerial photograph provided by the landowner of Village C, Henderson discovered a second, smaller village to the southwest (Village D) (Figure 3.4). In 1999, Henderson, David Pollack, members of the Kentucky Archaeological Survey, and volunteers from Georgetown College conducted a shovel test survey on the adjacent properties. The spatial distribution of archaeological features and artifacts led to the discovery of two additional villages (Villages A and B) (Henderson and Pollack 2000), but because these villages were not visible in the aerial image given to Henderson, the exact location and organization of Villages A and B was speculative.


**Figure 3.4. NRCS Aerial Photograph (1940s) given to Henderson by Jeff Singer. Both villages C and D are visible in the upper left corner of the image. Red markings are unrelated to this study.**

<u>Review of Historical Aerial Photos and Test of Geophysical Methods</u>

Uninvestigated archaeological deposits were present at Singer-Hieronymus prior to this research, but the scope of these deposits was unknown. After looking through the United States Geological Survey (USGS) aerial imagery archive, a 1952 aerial image was found that exhibits two large circular soil stains in the approximate locations where deposits associated with Villages A and B had previously been recorded (Henderson and Pollack 2000). Co-registration of the 1940s NRCS photo and 1952 photo shows all four villages in their precise geographic positions (Figure 3.5). Based on the locations of these circular crop marks or soil stains, we centered a 90 x 90 m area over the stain associated with Village B (Figure

3.5) to test the three geophysical methods at our disposal: MG, GPR, and EMI. Instruments used included a Bartington Grad601-2 fluxgate MG, GSSI SIR4000 GPR with a 400 MHz antenna, and Geonics Limited EM38-MK2 Ground Conductivity Meter (EMI).

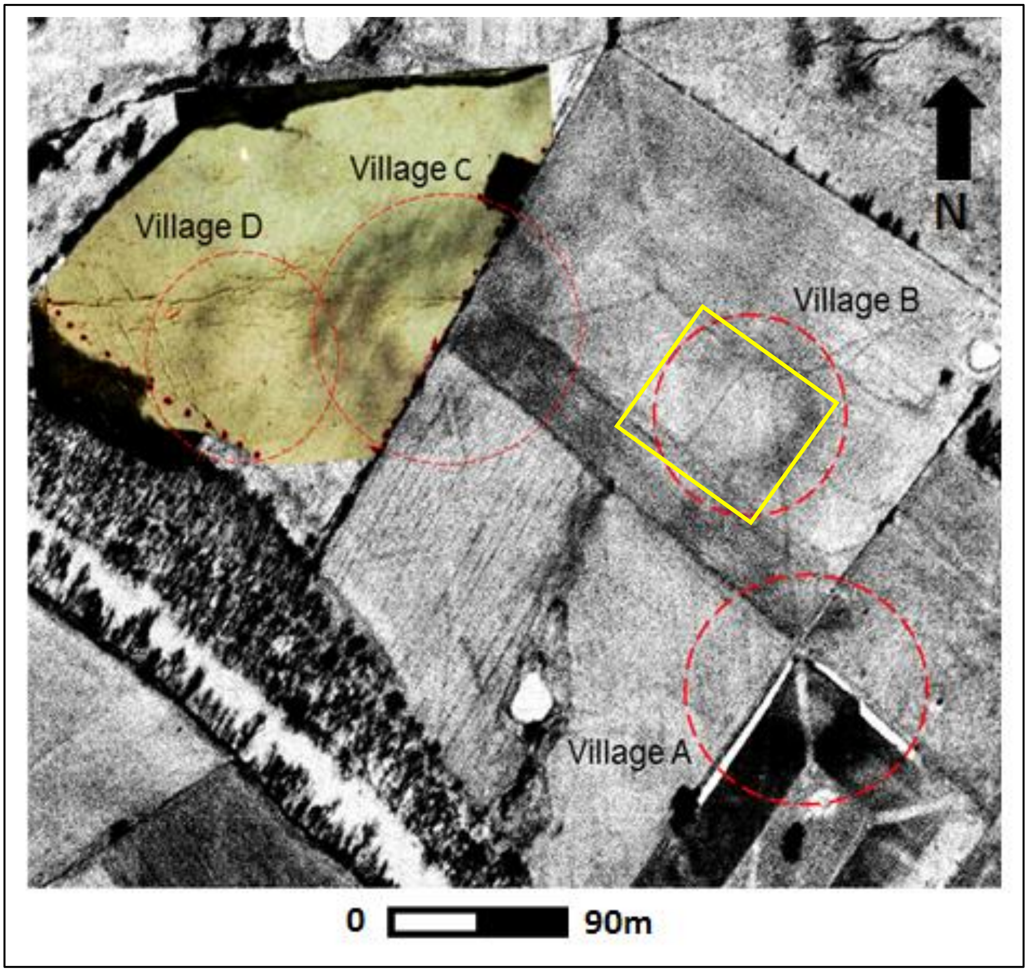


**Figure 3.5. Combined 1952 USGS Aerial Image (base image) and Overlaid NRCS image (late 1940s). Combined, these images show the location of villages A – D across the landscape. The yellow square denotes the initial 90 x 90 m geophysical survey area.**

<u>Geophysical Test Results</u>

All geophysical data were evaluated for effectiveness by analyzing and comparing results and excavating select areas. EMI was by far the most effective method, but MG and GPR results were useful once put into context based on EMI. Discrete features were mapped by identifying midden areas by high $EC_a$ and $MS_a$, cross-referencing GPR radargrams within these areas, and extracting a 2 cm soil core to test anomalies with high potential. A sample of positively identified features was then excavated in the 2017 University of Kentucky summer field school. A total of 17 refuse pits, two hearths, and portions of three house structures were pinpointed by this method and excavated (detailed results will be published separately). Soil characteristics observed during excavations helped understand the geophysical results and why MG and GPR were only marginally effective compared to EMI.

Magnetic Gradiometry

Results of the test survey showed that MG worked well to map soil erosion and deposition patterns across the landscape, but archaeological features were not visible (Figure 3.6). The dendritic pattern of high magnetism spanning most of the survey area is interpreted as rill erosion, a type of soil erosion formed by concentrated water runoff, forming streamlets. Rill erosion is a consequence of repeated plowing, which loosens the soil, followed by heavy rainfall that is too rapid to be absorbed into the ground. Topsoil, which is known to be more magnetic than subsoil (Dalan 2006), is entrained in the water runoff, which carves small channels as it flows downslope, and then deposited in these channels as runoff slows and eventually stops. The west to east direction of these erosional channels shows that they originated from the hilltop running downslope (east).

In addition, excavations showed that there are intact archaeological features beneath the plow zone, but plowing was deep (0.30 m) and features had been significantly impacted. In some cases, only the basal portions or roughly 0.10 m of the feature remained intact. In other cases, features had plow scars cutting completely through them. Remaining features are therefore only thinly stratified, often broken by plowing, and are situated beneath the thick plow zone dissected by prominent magnetic streamlets. Given that the strength of magnetic fields falls off with the third power of distance, it makes sense that these archaeological features are masked by the colluvium-filled channels above them.

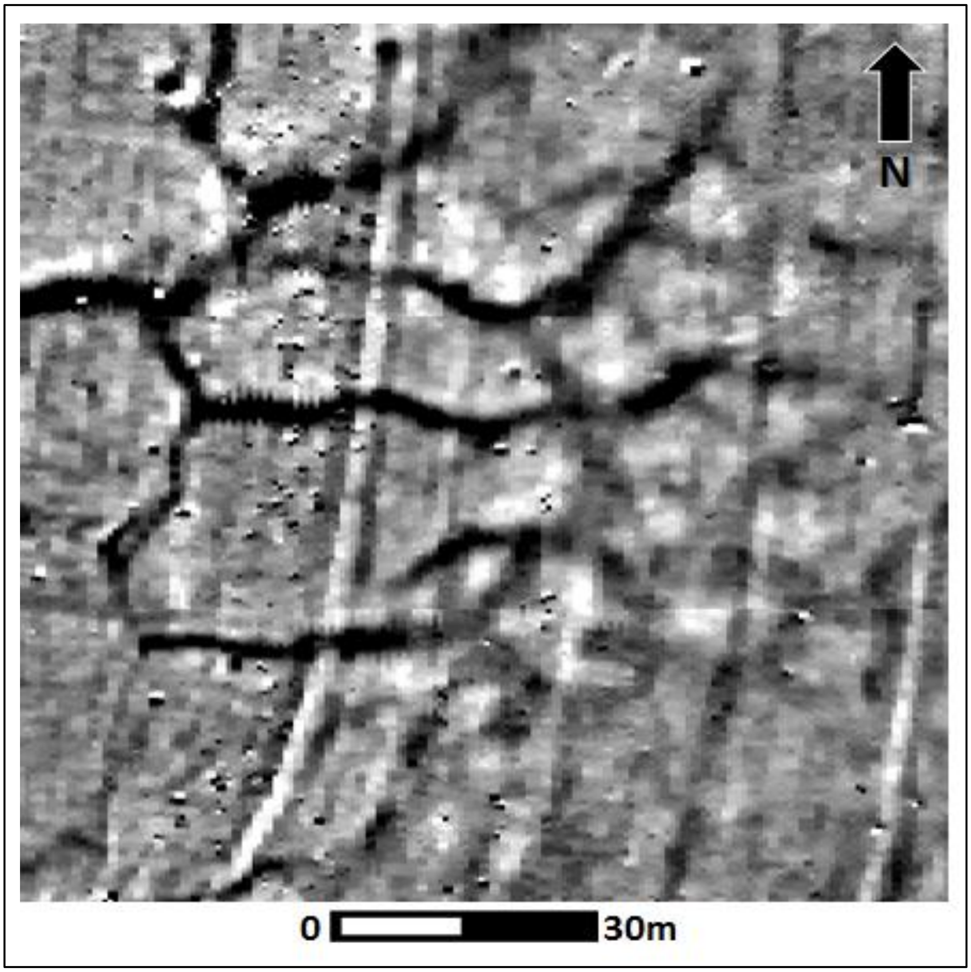


**Figure 3.6. Results of MG Test Survey. The dendritic pattern running east to west is likely rill erosion. The north to south linear features represent terraces built in the 1940s to prevent soil erosion.**

Ground-Penetrating Radar

GPR slice maps did not reveal clear archaeological features, but after detailed analysis of the radar reflection profiles, some pit features were identified (Figure 3.7). The poor preservation of archaeological features as previously discussed could partially explain why GPR depth slices did not clearly show them. Another contributing factor is the presence of a .05 – 0.10 m thick hardpan at the base of the plow zone, which keeps archaeological features and soils beneath it dry most of the time. Pooling water on top of a hardpan can cause false-positive radar reflections in GPR data making single depth slice maps very difficult to interpret (Conyers 2002). Hardpans can be created by repeated tilling at the same depth and exacerbated by frequent wheel traffic. As water percolates through the top soil it can begin to pool once it contacts areas of impervious, untilled soil. In addition, the subsoil is high in clay, making a hardpan more likely to form.

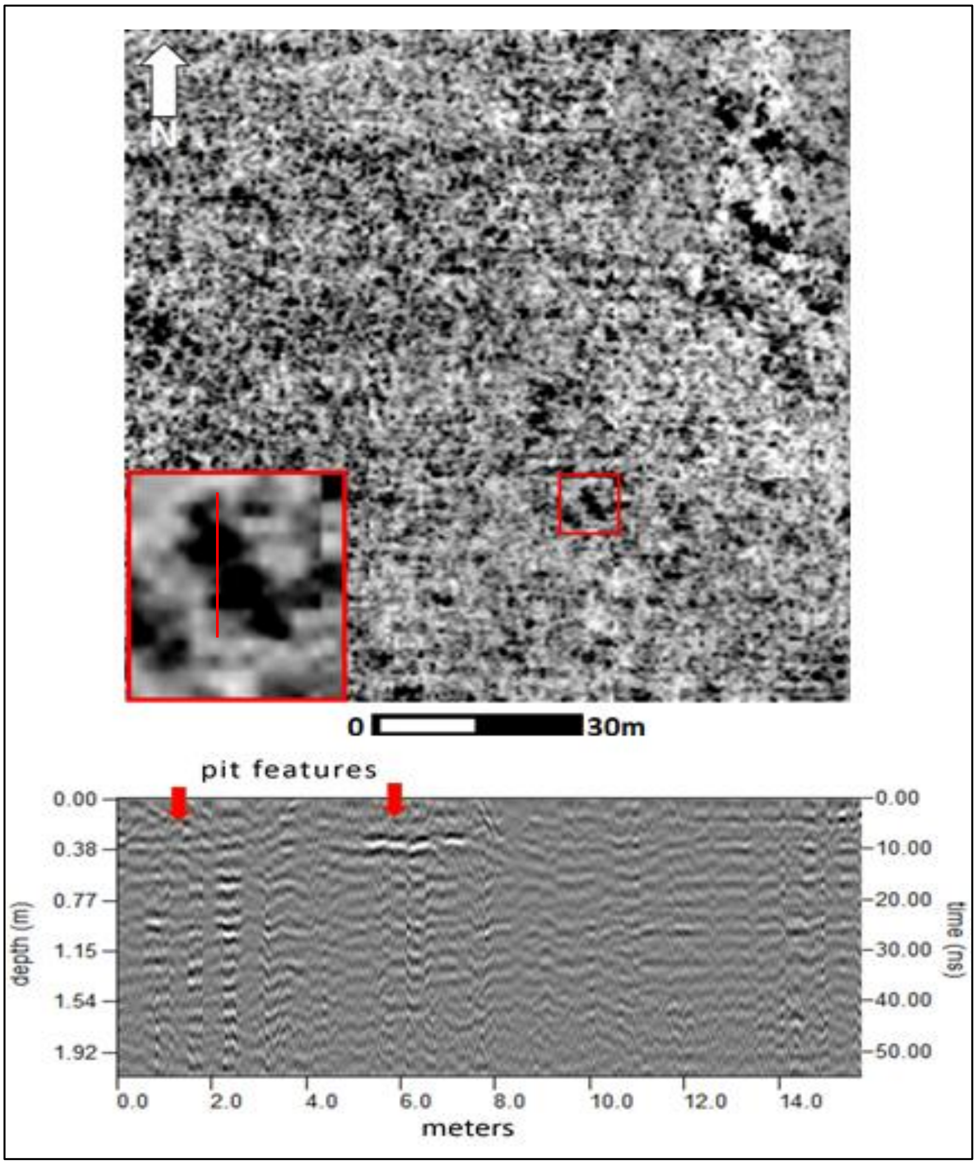


**Figure 3.7. GPR Depth Slice at 0.34 m Below Ground Surface. The radar reflection outlined in red represents two overlapping refuse pits. The red line running through these trash pits represents the transect that produced the subsequent radargram. In this radargram, the profiles of two overlapping trash pits are represented and denoted by the red arrows and labeled.**

Electromagnetic Induction

The EMI results were by far the most productive for archaeology in the test area because $EC_a$, and to some extent $MS_a$, very clearly show the same circular feature seen in the 1952 aerial image (Figure 3.8). This success may be due to favorable soil morphology, proper survey sampling density, and a good match between feature depth and EMI peak response depth for the EM38-MK2. Elevated $EC_a$ is a product of soil porosity, increased organic matter, and moisture (McNeil 1980; Bevan 1983). Soils associated with refuse deposits such as the ring-shaped midden at Singer Hieronymus are porous, organically rich, and hold more moisture. Additionally, unlike the MG results, the $MS_a$ is not adversely affected by the rill erosion pattern. Indeed, there is no evidence of this in the $MS_a$ data. This is likely because $MS_a$ measured by EMI is calculated differently and is sensitive to different depths than MS measured by MG. It is clear from these results that EMI can detect magnetically susceptible features that are invisible in MG.

Peak EMI depth response played an important role in the success of identifying refuse disposal areas. As shown in Figure 3.2 and reported in Table 3.1, the peak sensitivity of $EC_a$ measurement using 1.0 m coil spacing is roughly 0.40 m below surface, and 0.20 m below surface at a 0.50 m coil spacing. The historic plowzone on the site ranges from 0.20 – 0.30 m below surface. During excavations, archaeological features ranged from the base of the plow zone to roughly 0.50 m below surface. Therefore, the sensitivity of both the 0.50 and 1.0 m $EC_a$ were optimal for the detection of these buried deposits.

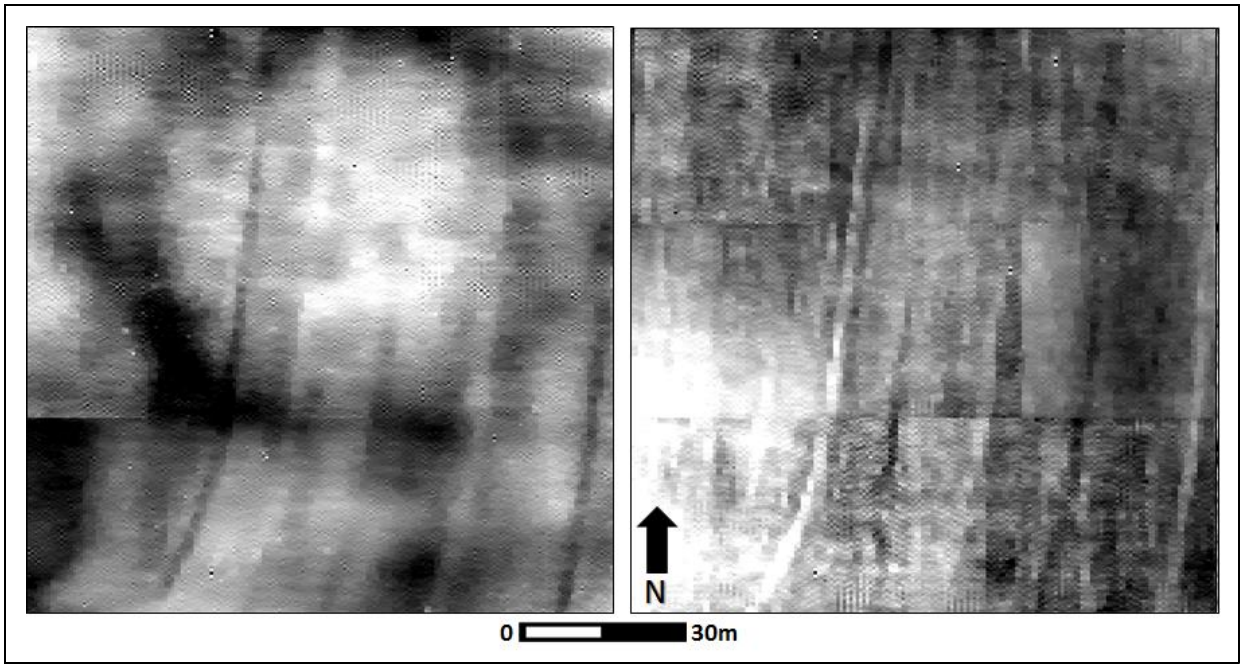


**Figure 3.8. EMI Results Showing Both $EC_a$ (left) and $MS_a$ (right) at 0.5 m Coil Separation. Note the circular signature. This represents refuse disposal areas outlining the village.**

Based on the results of the test geophysical survey, the EMI survey was expanded to a landscape scale at Singer-Hieronymus. In conducting landscape EMI, it was predicted that the refuse disposal areas of the remaining villages could be detected, helping to map their organization and extents. Additionally, if any unknown villages existed on landscape, they may also be detected in a widespread EMI survey.

Landscape-Scale EMI Survey

Our preliminary geophysical test surveys and subsequent excavations showed that EMI held the greatest potential for mapping villages at Singer-Hieronymus. By integrating RTK GNSS with the EM-38-MK2 and towing them behind a lawn tractor, in a thirteen-hour period spread over two days, a little over 4.7 ha of EMI data were collected (Figure 3.9). Non-surveyed areas were either inaccessible due to overgrown vegetation, pasturing animals, or lack of time. To transport the instrument, a non-magnetic sled was constructed from an ice-fishing hull, Styrofoam was used to encase the instrument to protect it from debris, and a PVC pipe rack was constructed above the instrument to house the external battery pack, data collector, and GNSS receiver. A gear drive transmission lawn tractor was selected to pull the sled (Figure 3.9). The gear drive transmission configuration enabled relatively constant speed on variable grades of terrain, ensuring that equal space was consistently maintained between instrument readings, which are logged in time along transects. Data were collected at a velocity just over 8 km per hour. To prevent magnetic interference between the lawn tractor and instrument, the sled was kept at a fixed distance of three meters behind the lawn tractor. At the beginning of each day, the instrument was calibrated. The instrument was set to collect 20 readings per second, and the data were collected in a zig-zag pattern at a 0.75 m transect spacing. For data processing purposes, a tie-line was collected at the end of the survey following the methods used by Delefortrie et al. (2014). The significance of tie-line collection will be discussed in the next section.

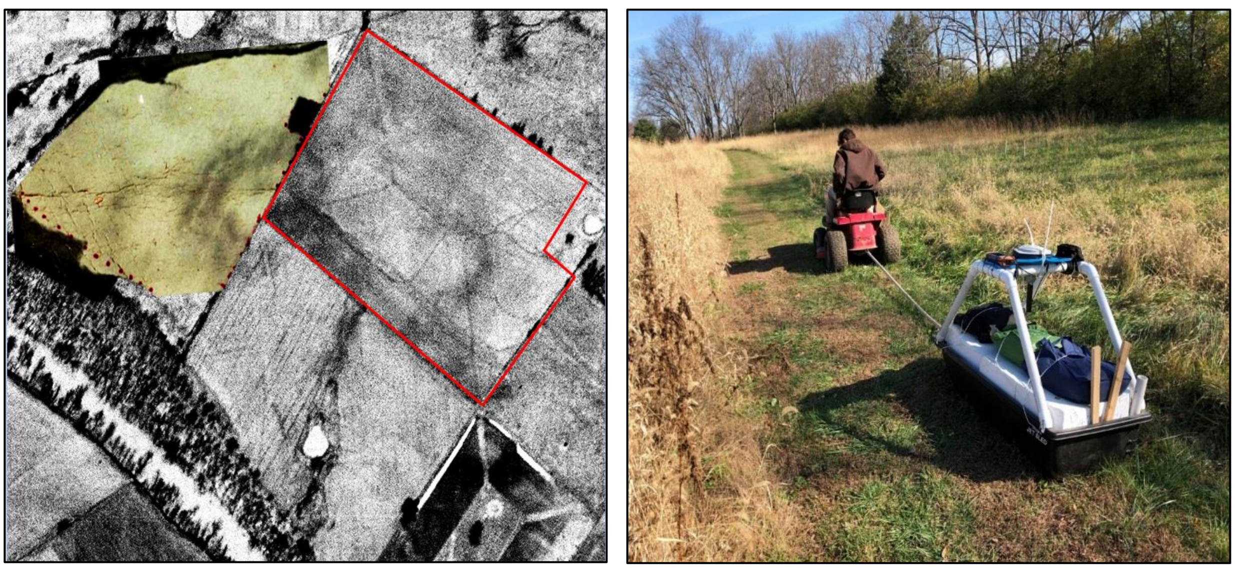

**Figure 3.9. EMI Survey Area and Mower Configuration. The left image represents the total area surveyed during the landscape EMI survey. The right image shows the lawn tractor-sled configuration used during the survey.**

## Data Processing

One disadvantage of EMI survey is signal drift. Signal drift refers to an instrument's inability to maintain a stable signal over time despite no dramatic changes either above or below ground (Delefortrie et. al 2014). Multiple contributors to drift have been suggested including the presence of rapid changing ambient temperature, incorrect instrument calibration, and instrument circuitry design (Sudduth et. al 2001; Robinson et. al 2004; Minsley et. al 2012). In other words, as an instrument's circuitry warms or cools, readings can become slightly unstable, and this instability can be exacerbated by incorrect or insufficient calibration procedures. Both EMI and MG instruments are susceptible to signal drift (Weymouth 1986; Delefortrie et al 2014), and although developments in instrumentation and data processing have made it much less problematic, it still exists.

To counteract drift, manufacturers of EMI instruments have begun to incorporate circuitry that compensates for heating and cooling of the electronics due to ambient temperature change (EM38-MK2 User Manual). Additionally, researchers have proposed multiple regimes for calibration, surveying, and data processing with EMI instruments (Sudduth et al. 2001; Robinson et al. 2004; Simpson et al. 2009; Minsley et al. 2012; Grellier et al. 2013; Delefortrie et al. 2014; De Smedt et al. 2016). Many proposed regimes are time consuming and may not adequately attend to the problem; however, one drift compensation procedure has been carried out successfully in European landscape-scale EMI survey. Delefortrie et al. (2014) proposed that by collecting data in a tie-line that spans the survey area, applying a time-based median filter, and fitting a spline curve to the residual signal values, signal drift can be modeled and corrected. The use of tie-lines were originally proposed by Weymouth (1986) to correct for magnetic variation in magnetometry surveys. A Tie-line is a rapid traverse that crosses the original survey data, usually in a "W" formation (Figure 3.10). By collecting it rapidly, theoretically, a tie-line will contain negligable drift and can therefore be used to adjust all survey readings to their true values.

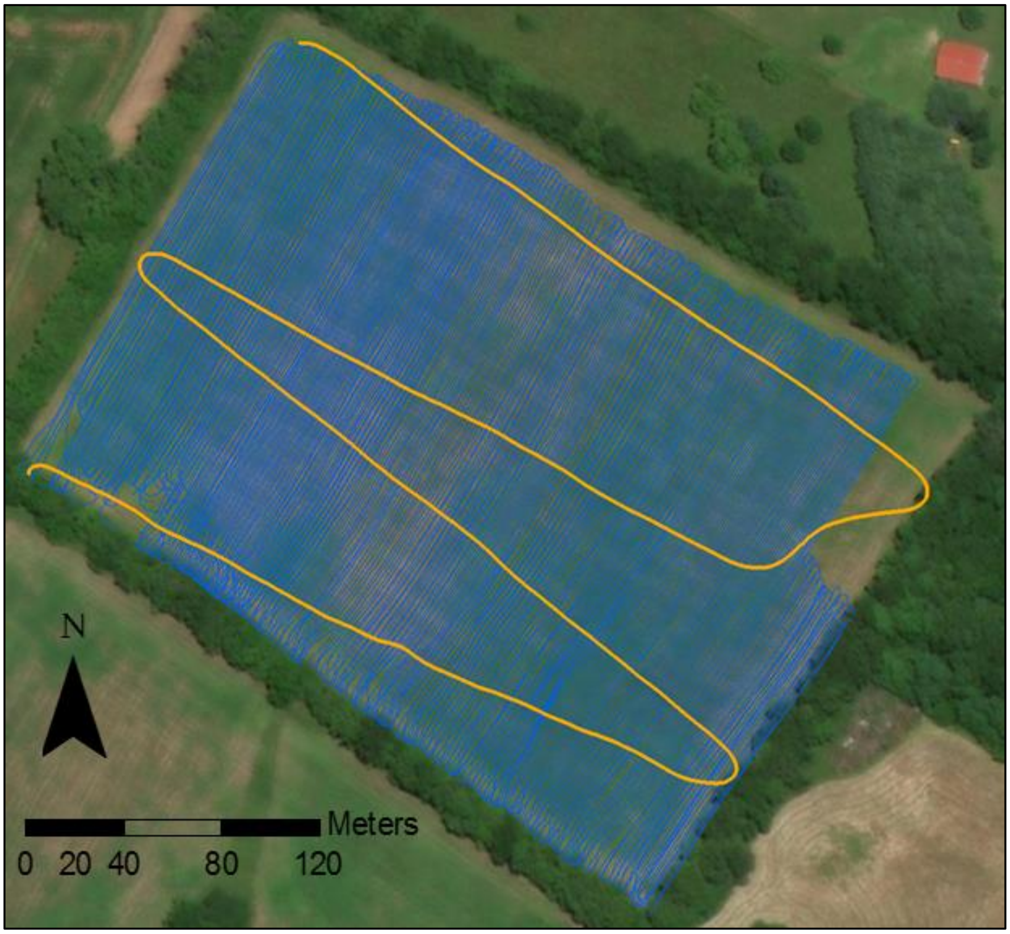


**Figure 3.10. Original Survey Lines (blue) and Tie-Line Data (orange)**

Once the survey and tie-line data were collected, measurements were converted to $MS_a$ and $EC_a$ for both coil spacings using DAT38MK2 software and then exported in comma-delimited format. Time latency associated with GNSS-based data collection was accounted for during the export process. Drift correction as previously discussed was done by modifying the MATLAB structure developed by Delefortrie et al. (2014). Also, because the survey data were collected over two days and calibration can vary from day to day, the timestamp of the second day was adjusted so as to create one continuous time series, and a constant was added to the second day data to match data value range of the first day. The files were then imported into the MATLAB structure, which was used to calculate residual survey data, apply a Hampel filter to remove outlying intensity values in the residual survey data through a user-defined search window (Pearson et al. 2016), and apply a spline curve to the filtered data to further smooth any residuals outlying values (Figure 3.11a-c). This process was applied to all four datasets collected by the EM38-MK2 in VDM, which includes both the 0.50 m and 1.0 m $EC_a$ and $MS_a$. Both the original and drift corrected datasets from each coil spacing were projected into WGS 1984 UTM Zone 16N and gridded using inverse-distance-weighting (IDW).

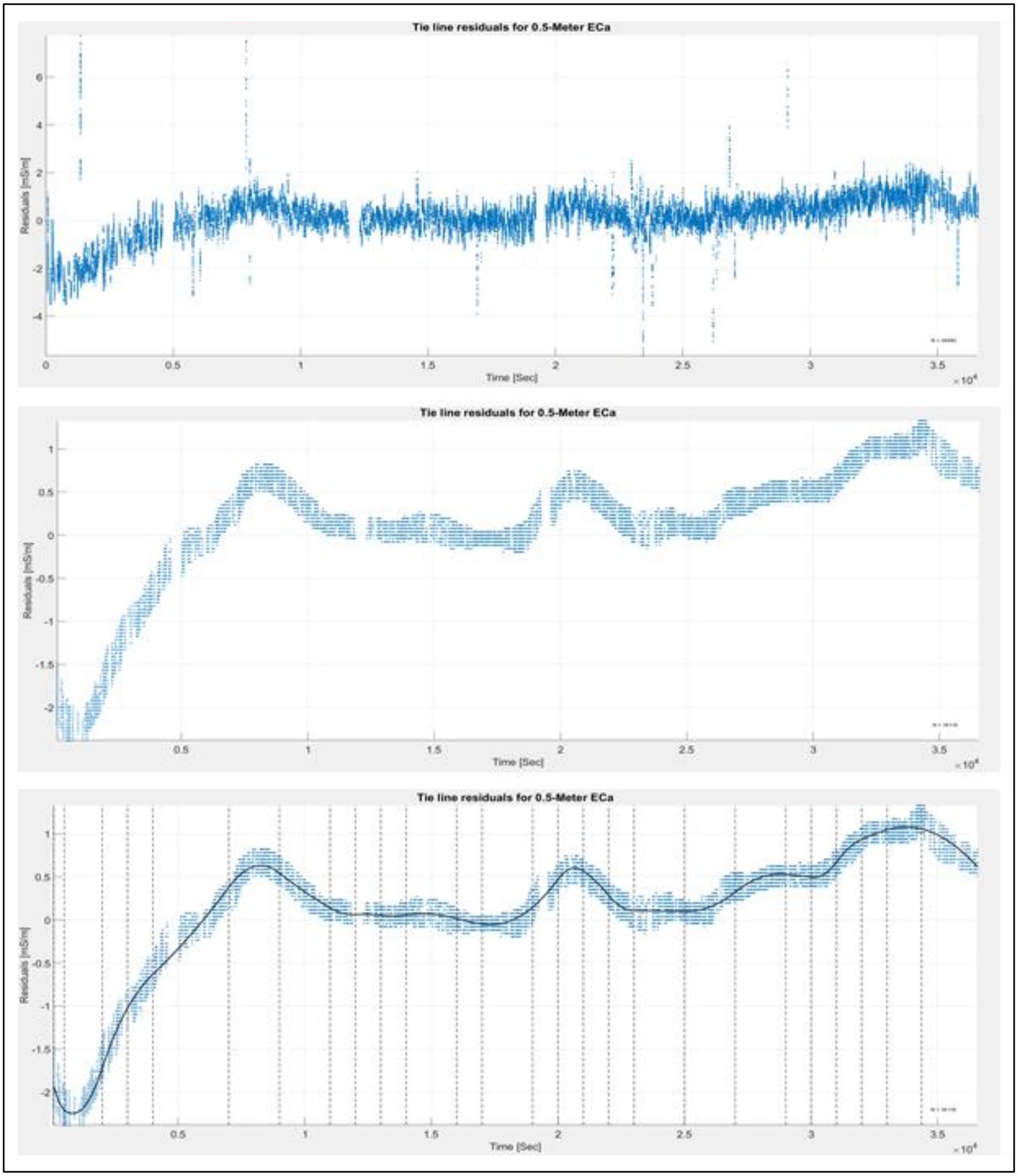


**Figure 3.11. Tie-Line Residuals with Applied Corrections. (a) tie-line residual data, (b) tie-line residuals with applied Hampel filter, (c) tie-line residuals with fitted spline curve.**

## Results and Discussion

As predicted, results of the landscape-scale EMI survey show the organization of known villages at Singer-Hieronymus. In addition, three potentially new villages were identified. $EC_a$ at both 0.50 m (Figure 3.12a-c) and 1.0 m coil separation (Figure 3.12e-f) captured the highly conductive soils associated with refuse disposal areas surrounding both villages B and C. The strong readings and large width of these refuse areas imply much about the intensity of occupation and population size of the villages. In addition to the variation between villages, it is important to note the general difference in total area of conductive soils between the 0.50 m and 1.0 m $EC_a$ datasets. This difference can be interpreted as directly related to the depth of peak EMI response of the 0.50 m $EC_a$ compared to the 1.0 m $EC_a$. The peak response of $EC_a$ in VDM at a 0.50 m coil spacing is 0.20 m, while the peak response of $EC_a$ in VDM at a 1.0 m coil spacing is 0.40 m. The difference in datasets is significant for two reasons. First, having higher $EC_a$ at a 1.0 m coil separation compared to 0.50 m indicates that soils at 0.40 m are more conductive than at 0.20 m. This implies that more substantial archaeological deposits are producing higher $EC_a$ at 0.40 m. This information makes it possible to roughly estimate the depth of archaeological features using EMI. Secondly, despite having lower conductivity in the 0.50 m $EC_a$ data, because peak response is 0.20 m and this depth is still within the plow zone at Singer-Hieronymus, it indicates that EMI may be capable of capturing archaeological signatures that have been disturbed and dispersed within a plow zone.

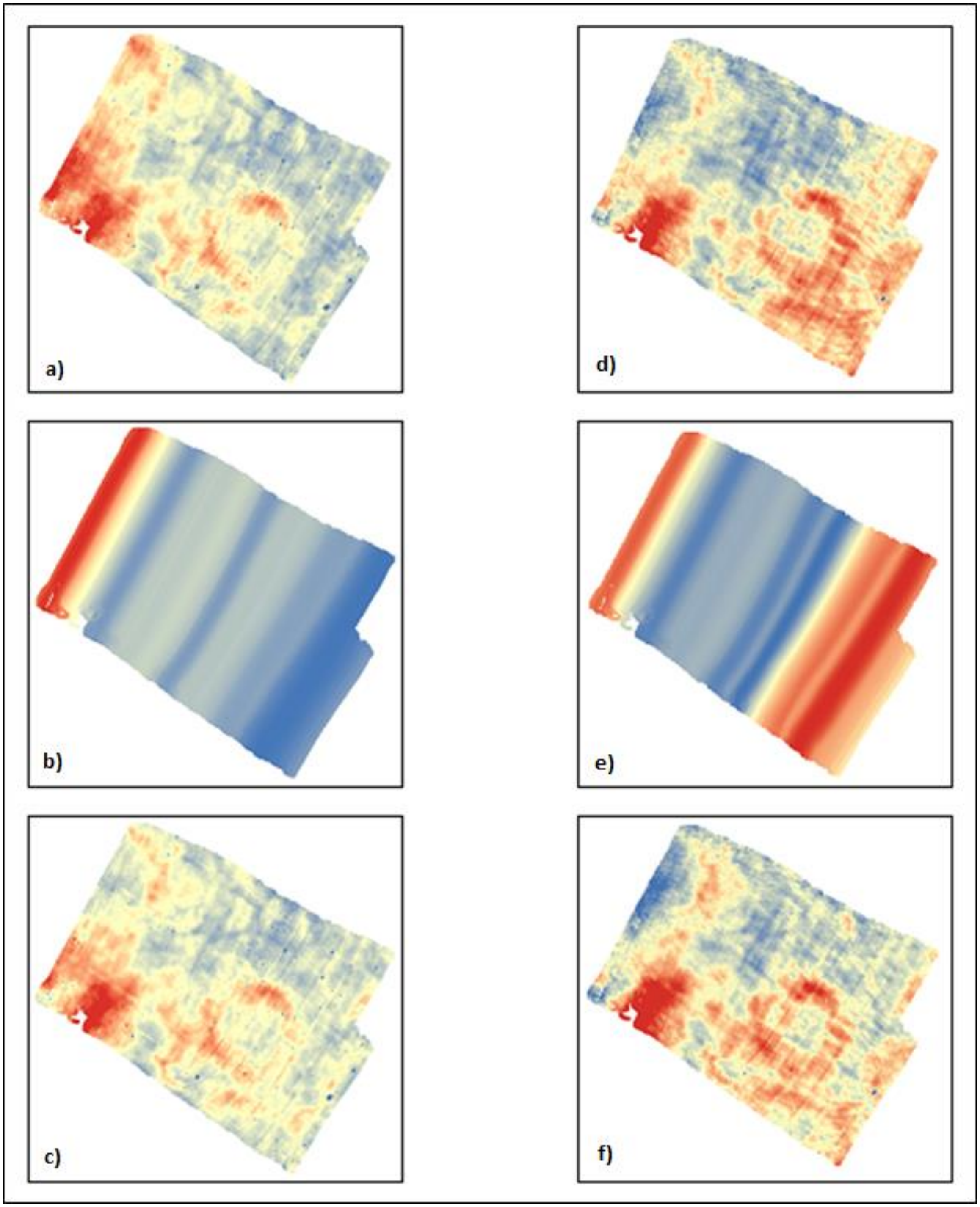


**Figure 3.12. 0.50 and 1.0 m VDM $EC_a$ data. (a) original $EC_a$ survey data at 0.50 m coil separation, (b) tie-line residual data of the 0.50 m $EC_a$ dataset. Note the drift visible at the beginning of the survey (top left), (c) drift corrected $EC_a$ at 0.50 m coil separation. Note the semicircular pattern (top) revealed by drift correction, (d) original $EC_a$ survey data at 1.0 m coil separation, (e) Tie-Line residual data of the 1.0 m $MS_a$ dataset. Note the drift visible at the end of the survey (bottom), (f) Drift Corrected $EC_a$ at 1.0 m coil separation. Note the ovular signature (bottom) better defined by drift correction.**

In contrast to $EC_a$, apparent magnetic susceptibility is only conclusive archaeologically at a 0.50 m coil separation (Figure 3.13a-c). Similar to $EC_a$, $MS_a$ also captures the distinct soils associated with refuse disposal areas surrounding the villages at Singer-Hieronymus. In the 0.50 m $MS_a$ data, both villages B and C are captured. Interestingly, unlike $EC_a$, a small section of Village A was also captured in these data in the bottom corner of the survey area. Although 1.0 m $MS_a$ data were not conducive for mapping archaeological deposits, the difference between $MS_a$ at 0.50 and 1.0 m coil separation is important to note. When looking at the 1.0 m $MS_a$ data, we see linear patterns interpreted to be associated with plow activity. The peak signal response of 1.0 m $MS_a$ is 0.22 m 0.12 m for 0.50 m $MS_a$. Because of this, we could infer that farming activity ultimately influenced the magnetic susceptibility at lower depths through the dispersal of magnetically susceptive soils. This indicates that $MS_a$ at 1.0 m coil separation and MG were not invalid data, but archaeological deposits were masked by subsurface disturbances. The ability to measure $MS_a$ at varying depths and produce separate datasets gave EMI an advantage over MG at Singer-Hieronymus. Finally, similar to $EC_a$, $MS_a$ at 0.50 m coil separation is measuring peak responses within the plow zone, reinforcing the suggestion that EMI may be useful for detecting disturbed archaeological signatures within plow zones.

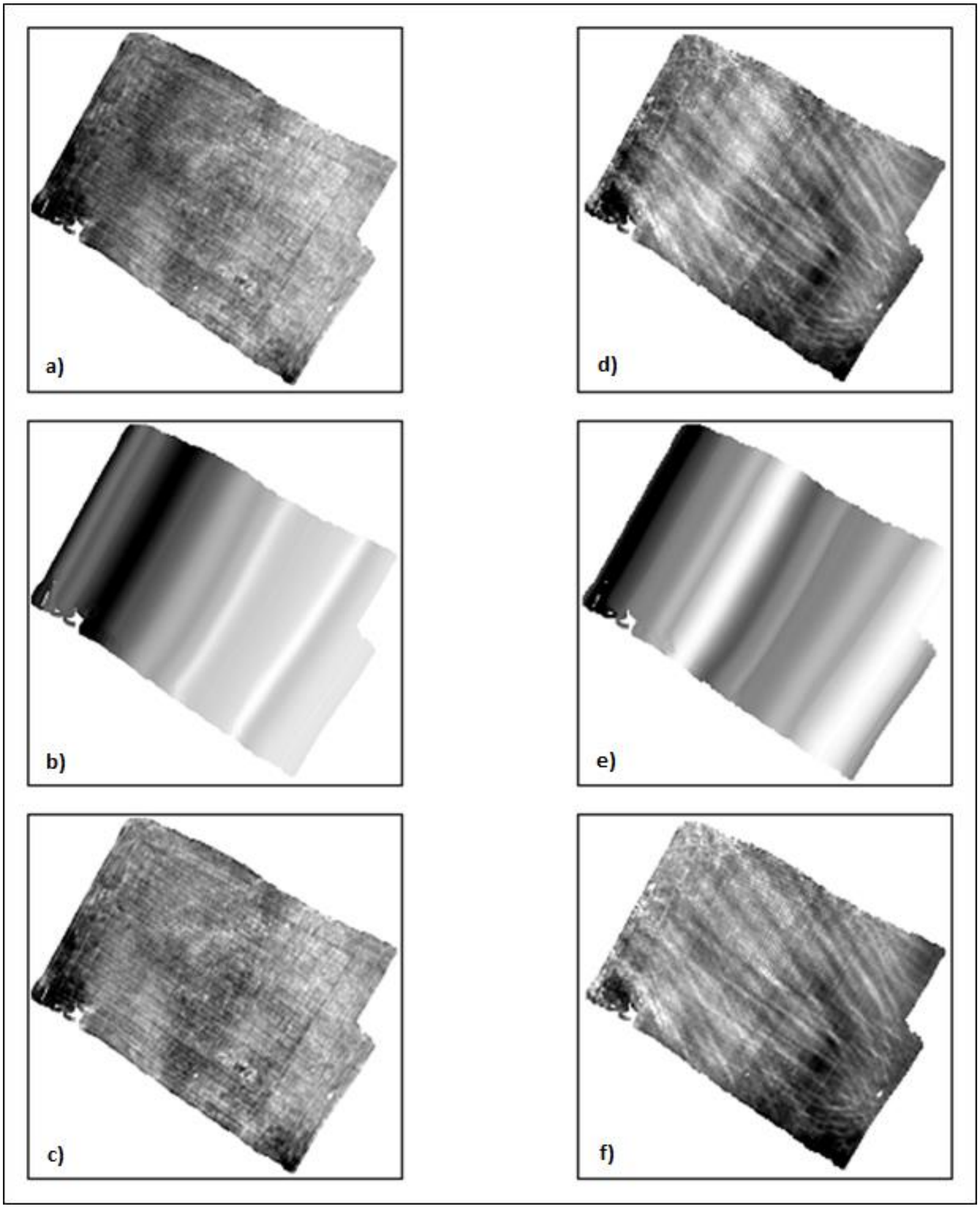


**Figure 3.13. 0.50 and 1.0 m VDM $MS_a$ data. (a) original $MS_a$ survey data at 0.50 m coil separation, (b) tie-line residual data of the 0.50 m $MS_a$ dataset. Note the drift visible at the beginning of the survey (top left), (c) drift corrected $MS_a$ at 0.50 m coil separation, (d) original $MS_a$ survey data at 1.0 m coil separation, (e) tie-line residual data of the 1.0 m $MS_a$ dataset. Note the drift visible at the beginning of the survey (top left), (f) drift corrected $MS_a$ at 1.0 m coil separation.**

As expected, all datasets exhibited signs of instrument drift, and while it not a major problem, it was still present. When looking at the original 0.50 m $EC_a$ dataset (Figure 3.12a), drift is most dramatic in the beginning of the survey (top left). This becomes evident after examining the residual data (Figure 3.12b). Drift in the beginning of an EMI survey is likely due to fluctuation in instrument circuitry temperature. Once drift is removed, the boundary of Village C is more defined, and a new semicircular feature exhibiting higher $EC_a$ becomes visible at the very top of the dataset (Figure 3.12c). Within the 1.0 m $EC_a$ dataset, drift is more visible closer to the end of the survey (bottom right) when comparing the original data to the residuals (Figures 3.12d and 3.12e). After removing drift from the 1.0 m $EC_a$ dataset, another ovular shaped signature becomes visible at the very bottom of the dataset (Figure 3.12f). Although this signature is somewhat visible in the 0.50 m $EC_a$ data, it is much more distinct in the 1.0 m $EC_a$ data. When examining the 0.50 m $MS_a$ dataset and residuals, similar to the 0.50 m $EC_a$ data, drift is present at start of the survey (Figures 3.13a and 3.13b). When this dataset is corrected, an almost complete circular signature becomes clear in the data just above Village B. Because the 1.0 m $MS_a$ dataset is not suitable for mapping archaeological signatures, drift correction was applied (Figures 3.13d-f) but the results will not be discussed.

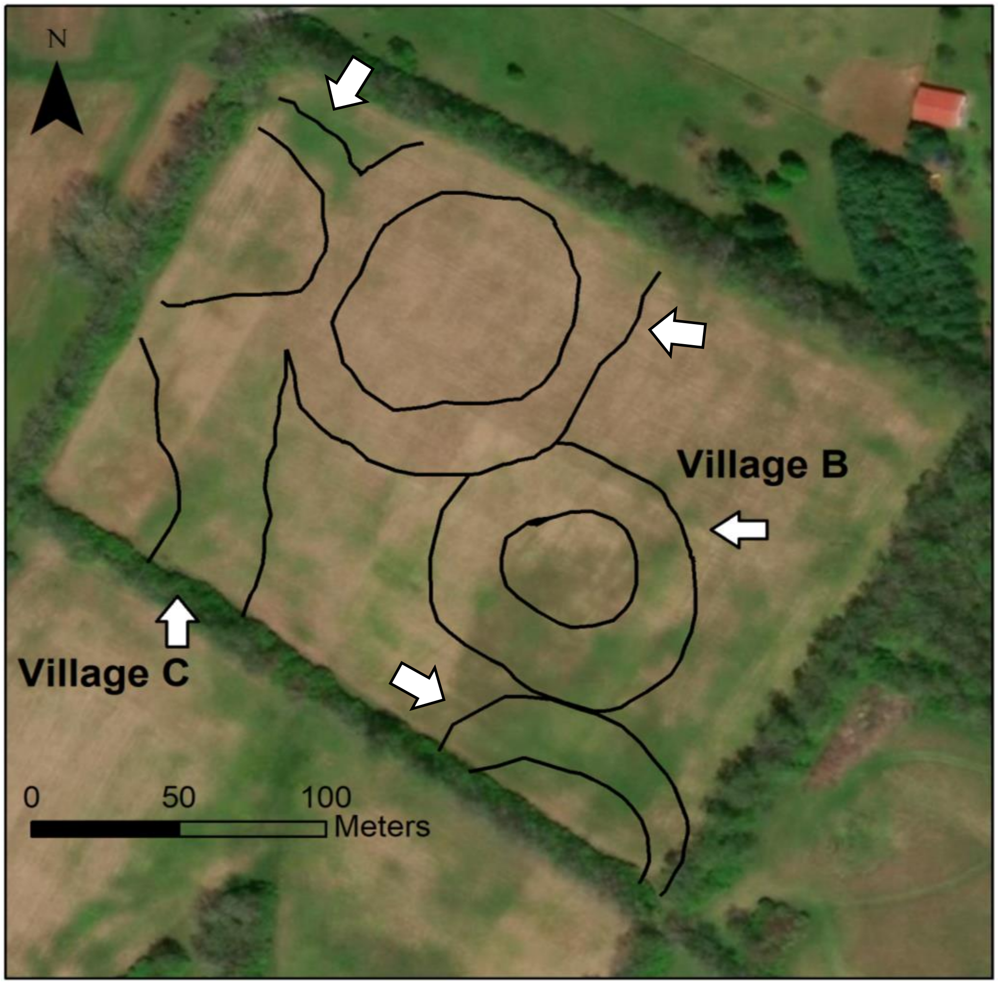


**Figure 3.14. Vectorized Results of the Drift Corrected 0.50 m and 1.0 m $EC_a$ and 0.50 m $MS_a$ in VDM. Note the location of Village B and C. New signatures were identified in the $EC_a$ datasets adjacent to the northern boundary of Village C and the southern boundary of Village B, and a new signature was identified in the $MS_a$ dataset adjacent to the northern boundary of Village B.**

## Conclusion

In this study, historic aerial imagery was analyzed and placed within a GIS to determine the locations of soil signatures suspected to be buried archaeological deposits at the Singer-Hieronymus Site Complex in central Kentucky. Afterwards, a multi-stage geophysical approach was used to determine the effectiveness of MG, GPR, and EMI in detecting these buried deposits. MG provided the poorest results and only identified areas of erosion. GPR provided similarly poor results when looking at depth slice maps, but detailed analysis of the radargrams located discrete archaeological features. EMI was by far the most effective method employed. $EC_a$ provided positive results with both coil separations while $MS_a$ only produced positive results with the 0.5-meter coil separation. Both were successful in delineating soil signatures. Further, these areas were tested through excavation. During the excavation, soil properties, stratigraphy, and agricultural disturbance was noted and interpreted as the probable cause for the poor results provided by MG and GPR.

Because of the initial successes of $EC_a$, a landscape scale EMI survey was conducted. In doing so, a little over 4.6 ha. of data were collected in a relatively short period of time using a GNSS-based mobile configuration. This survey utilized a tie-line method of data collection. MATLAB was used to adjust the original survey data and negate the effects of signal drift by applying a time-based median filter and spline curve. All four sets of data collected by the EM38-MK2 were then gridded using an inverse-distance-weighted interpolation method. Upon analysis of the drift corrected data, as expected, $EC_a$ detected portions of the refuse disposal areas associated with villages A, B, and C. The success of $EC_a$ was interpreted to result from a combination of feature morphology, the breadth of the disposal areas, and the close agreement between feature depth and optimal instrument depth sensitivity. In the process, three additional semicircular soil signatures were detected. From a combination of artifact and feature densities recorded from a previous shovel test survey, and similar geophysical trends confirmed to be archaeological deposits, these are suspected to be the refuse areas of three additional undocumented villages. These signatures will undergo additional geophysical and archaeological testing in the future.

The benefits of EMI are clear. Each component of the EMI dataset provided useful information for understanding the organization of villages at Singer-Hieronymus. Through the identification of new signatures, it has allowed a more thorough understanding of the Native American use of the landscape at Singer-Hieronymus. If our investigations were limited to MG and GPR, we would not likely have discovered new villages, and would have logically concluded that the villages visible in historic aerial photos have since been eroded given the pattern of rill formation that dominates the MG test survey results. This study shows that EMI is a very useful method that has been underutilized but shows much promise as instrumentation and data processing methods continue to advance.

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# CHAPTER 4

## DISCUSSION AND CONCLUSIONS

The objective of this thesis was to investigate the temporal and spatial relationships of the Middle Fort Ancient villages at the Singer-Hieronymus Site Complex in central Kentucky in an attempt to create an occupational sequence of the site's Middle Fort Ancient occupation. A combination of aerial imagery analysis, geophysical survey, GIS, and archaeological excavation was used to determine village shape, size, and internal organization of Villages A, B, and C. Additionally, diagnostic material objects and material culture attributes were utilized in conjunction with radiometric data to determine the ages of the villages.

The results of the spatial analysis concluded that Villages A, B, and C were all circular in shape, and while Villages A and B were about the same size, Village C was larger, suggesting a larger population. Additionally, internal organization of the villages was similar to that of Site 15Hr22 of the Florence Site Complex, which features a plaza with three distinctive activity zones encircling it. These zones – moving outward from the plaza – are the mortuary zone, residential zone, and refuse disposal zone. Results of the material culture analysis concluded that there was too much overlap materially and chronometrically to sequence the Middle Fort Ancient occupation at Singer-Hieronymus. However, these data suggest that the Singer-Hieronymus Site Complex was occupied between A.D. 1275 and the end of the Middle Fort Ancient period (A.D. 1400). This significant overlap suggests that the Singer-Hieronymus site locale was occupied continuously during this time.

A continuous occupation at Singer-Hieronymus holds important implications. While it is likely that the Middle Fort Ancient villages at Singer-Hieronymus did shift due to population growth, there is no evidence to suggest that the site locale was abandoned after its initial occupation around A.D. 1275 until the end of the Middle Fort Ancient period 125 years later. Therefore, these results suggest that the occupation of the Singer-Hieronymus locale did not follow the model of Fort Ancient village movement occurring every 10 to 30 years, and thus environmental degradation was not an issue for these village inhabitants. Researchers should consider the role that ideologies, such as power of place and identity, played in Fort Ancient settlement decision.

Because of the initial success of electromagnetic induction (EMI) survey in mapping archaeological features at Singer-Hieronymus, a landscape-scale EMI survey was conducted in an attempt to locate additional villages at the Singer-Hieronymus locale. In doing so, a little over 4.6 ha. of data were collected using a GNSS-based mobile configuration. This survey utilized the tie-line data collection method and applied a time-based median filter and spline curve in MATLAB to negate instrument drift (Delefortrie et al. 2014). Upon analysis of the data, three additional possible villages at Singer-Hieronymus were discovered. Thus, it is recommended that additional work be conducted at Singer-Hieronymus to obtain additional data to remove sampling bias from the material analysis conducted, to archaeologically test these additional signatures to confirm or deny their archaeological significance and obtain ages for these occupations, and to critically consider the factors that contributed to the long Fort Ancient occupation of this Scott County ridgetop.

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