High Resolution Mapping and Geophysical Assessment of the Gast Farm Site (13LA12), Southeast Iowa

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Introduction

This report is one part of a two-part submission to the National Geographic Society (NGS) and the Spatial Archaeometry Research Collaborations (SPARC) program of the Center for Advanced Spatial Technologies, University of Arkansas. The submission presents the results of an archaeological and archaeo-geophysical research project focusing on prehistoric community patterns in the Mississippi River valley in southeast Iowa. In this part of the submission, we supply information on overall project goals, the study site, the history of research, aerial imaging, high-resolution mapping, and selected aspects of mounds, habitation features, and dating. The second part of the submission, prepared by Adam Wiewel and Steven De Vore, discusses methods, results, and interpretations of the geophysical survey.

Fieldwork and analyses were conducted in 2016-2018 through a grant from the NGS Committee for Research and Exploration (project 9938-16) with technical assistance from SPARC. A Beloit College Keefer Senior Faculty Grant and a developmental leave from Beloit College supplemented the NGS and SPARC support. Research was also aided by effort provided by Beloit College students and individuals at several partner institutions, notably the Midwest Archaeological Center of the National Park Service (Lincoln, NE; MWAC), the Office of the State Archaeologist of the University of Iowa (OSA), and Arizona State University.

Project Summary

The goal of this research is to understand the structure of the Woodland communities at Gast Farm, a 13-hectare site located in the Mississippi River valley in southeast Iowa (Figure 1). Gast Farm is one of the largest and best-preserved Woodland sites in the region. The site's near-surface components are primarily Middle Woodland (Havana-Hopewell, ca. 50 B.C.–A.D. 250) and initial Late Woodland (Weaver, ca. A.D. 350–500). There is essentially no mixing of deposits from the two occupations, a rare occurrence at multicomponent sites. Additionally, a large mound was once present, and we suspected remnants of geometric earthworks also existed (Benn and Green 2000; Green 2017; Whittaker and Green 2010). Studies at Gast Farm therefore can contribute to knowledge of Middle and Late Woodland domestic and corporate-ceremonial spheres, i.e., residential as well as sustainable and symbolic communities (Carr 2006; Smith 1992).

While earlier studies had identified the location and approximate size of the Middle Woodland occupation area, its layout and thus its internal organization could not be determined. The plan of the Late Woodland village was more clearly discernible: it was apparently organized as a habitation ring surrounding an open plaza. But this was a supposition based mostly on aerial imagery and the distribution of surface-collected artifacts. Therefore, determination of the structure and organization of both communities required additional work.

Employing geophysical survey, aerial imagery collection and rectification, and GIS development, the project: (1) identified the Middle Woodland (Havana-Hopewell) community plan, (2) determined no geometric earthworks were present but discovered six additional mounds, and (3) confirmed and expanded the Late Woodland (Weaver) community plan. In the process of obtaining these results, the project also accomplished several methodological advances: it (1) demonstrated the viability of magnetic gradiometry for identifying Woodland residential and mortuary features in Mississippi Valley alluvial fans, (2) showed how to incorporate legacy oblique aerial photography in a georeferenced GIS, (3) indicated the promise of drone-based photogrammetry in identifying cultural features beneath crop cover, and (4) modeled the virtual reconstruction of leveled mounds.

Site Setting

Gast Farm is located in the portion of the Mississippi River valley known as Muscatine Island. Not an island in the strict sense, Muscatine Island is a broad, 130 km^2 expanse of stream channels, lakes, floodplain, and terraces of late Wisconsinan and Holocene age (Bettis 2003; Bettis and Artz 1992; Hansen and Steinhilber 1977). It is bounded on the east by the present Mississippi River channel and on the west by the bluff line. A Mississippi River paleochannel that was active ca. 10,500-10,200 BP developed into a "large wetland with open water where deeper channels had been" around 10,000 BP. Between about 9000 and 2500 BP, "alluvial fans emanating from western tributaries prograded… and progressively buried the wetland." (Bettis et al. 1992:37-39). Over the past ca. 2300-2500 years, alluvial fan surfaces in Muscatine Island and elsewhere in the region have been relatively stable, experiencing minor amounts of deposition and erosion (Bettis 1988, 2003; Bettis et al. 1992, 2008). The surface soil and paleosols in much of the Gast Farm fan exhibit Bt horizons, consistent with radiocarbon data indicating surface stability for >2300 years (Benn 1988:B44-B47, B55-B62; Bettis et al. 1992:54-55).

Until about a century ago, the locality "contained a wide array of environments: well drained alluvial fan surfaces tucked against the valley wall, adjacent wet marshy areas, open quiet water bodies, excessively drained sandy terraces toward the valley center, and the Mississippi channel and its connected backwater areas" (Bettis et al. 1992:39). Muscatine Slough is a lazily flowing channel that now follows the course of the Mississippi paleochannel. The slough and other remnant channels and lakes enabled watercraft to access the Mississippi River main channel and islands from nearly anywhere in the locality. The bluffs bordering Muscatine Island rise ca. 45 m above the valley floor, marking the edge of loess-mantled Southern Iowa Drift Plain uplands (Bettis 1994a, 1994b; Prior 1991). The east side of the Mississippi River opposite Muscatine Island in Illinois is also characterized by a broad valley hosting a similar variety of Late Wisconsinan and Holocene landforms (Bettis 1988, 2003; Bettis et al. 2008).

Vegetation and hydrologic patterns as recorded by the 1837-1838 General Land Office survey and inferred from soil properties indicate that the Gast Farm site's position at the ecotone between Muscatine Island and the uplands afforded its inhabitants easy access to a wide range of prairie, savanna, woodland, wetland, lake, stream, and river resources (Anderson 1996; Brown 1988; Dunne 2002:53-55; Guldner 1960; Nelson et al. 1998). At

Gast Farm, the Mississippi valley is 12 km wide. Sloughs, floodplain marshes, backwater lakes, floodplain prairies, and floodplain and upland forests were all no more than a 10-15 minute walk from the site. General vegetation patterns ca. 2000 years ago probably did not differ much from those indicated by the historical and soils data (Baker et al. 1987).

Gast Farm is situated atop and within one of Muscatine Island's most prominent alluvial fans. Near the fan's apex, the deposit is ca. 12.5 m thick, but in the distal part of the fan where the Middle Woodland occupation is located, its thickness is ca. 3.5 m (Bettis et al. 1992). The main channel of the Mississippi River is 5 km to the east and Muscatine Slough borders the eastern edge of the site.

History of Investigations

In 1925, Iowa Archaeological Survey director Charles R. Keyes described Gast Farm as a "large site" on the "second terrace of Muscatine Slough. Flint chips and pottery fragments scattered over 30 acres or more. Numerous relics found here. The land has been under cultivation. Mississippi bluffs rise just to W. of site" (Charles R. Keyes notes, April 3, 1925, Louisa County folder, Keyes Collection County Notes, Office of the State Archaeologist, University of Iowa [OSA]). Keyes obtained this information from a local collector named Charles Anthony. Through the mid- to late-20th century, landowner Dan Gast and local collectors amassed large collections from the site. State Archaeologist Reynold Ruppé acquired sherds and lithics from the site in the 1950s (OSA accession 78). Gast apparently tried to interest Ruppé in a large mound near the center of the site, but possibly as a result of mutual misunderstandings, Gast leveled the mound. Examining the ground closely during earthmoving, he recovered copper axes, polished platform pipes, and sheet mica (OSA accession 7210). The mound, which was well known to collectors, appears on a collector's sketch map made in 1970 with the note "mound is gone can still see the site"—presumably the former site of the mound (T. Royster, ca. 1970; sketch map and notes on file, OSA). OSA archaeologists later made a small surface collection from Gast Farm (OSA accession 958-12; Till 1977:194-195) and recommended consideration of the site for designation as a State Preserve (Tiffany 1978:24).

Avocational archaeologist Ferrel Anderson took infrared aerial photos of the site in 1972 and 1974 (see Aerial Imagery, below). Landowner Dan Gast and other individuals continued to collect artifacts from the site in the 1970s and 1980s. Geological studies throughout the locality by E. A. Bettis III in the 1980s and 1990s defined a series of landform-sediment assemblages and refined regional understandings of landform evolution, archaeological site formation processes, and settlement patterns (Bettis et al. 2008).

Systematic archaeological fieldwork at Gast Farm began with a controlled surface collection in the spring of 1990, followed by excavations conducted by University of Iowa and Iowa Archeological Society field schools. Excavations in 1991 and 1992 uncovered 171 m^2 of the Middle Woodland component, while 120 m^2 of the Late Woodland community was excavated from 1991 through 1994 (Weitzel and Green 1994;

Whelan et al. 1991). Although the excavated areas amount to only about one percent of each component, dozens of features were recorded and nearly 300,000 specimens were recovered. Several theses, publications, and conference papers discuss material from these investigations (e.g., Dunne 2002; Johnson 2002; Neverett 2001; for a complete list of reports, see Green 2017). Collections and associated data are housed at the OSA repository (accession 3437).

Fieldwork resumed with the magnetic survey in 2016 (see Wiewel and De Vore, part two of this submission) and drone-based photogrammetric mapping and thermal imaging in 2017. Analysis of LiDAR and other remotely sensed data also proceeded throughout 2016 and 2017 (see Aerial Imagery, below). These geophysical and remote-sensing studies were employed to locate anomalies associated with the Middle and Late Woodland habitation areas and with the leveled mound and a possible geometric earthwork (Whittaker and Green 2010:35-39). Also in 2016-2017, we reexamined the Gast Farm site collections and submitted a series of radiocarbon samples to address questions regarding the timing and duration of the site's Middle Woodland occupation (see Dating, below).

Aerial Imagery

The project employed several forms of aerial imagery to detect cultural features, to interpret anomalies noted in the magnetic survey, and to serve as base maps for other forms of geospatial data. We consulted a multitude of black-and-white, panchromatic, and infrared images, as well as digital elevation data. Vertical photography from fixed-wing aircraft is available from as far back as the 1930s; high-altitude infrared images became available in the 1980s; and LiDAR as well as satellite-based imagery is now available as well. We also acquired our own imagery, the first set in 1990 as a series of high- and low-angle oblique Kodachrome photos from a low-flying fixed-wing airplane, and the second set in 2017 through drone-based digital photogrammetry and thermography. Methods and results of aerial imagery analysis follow.

Rectification of Oblique Imagery

A total of 24 oblique Kodachrome slides from the 1990 flight were scanned and submitted as tifs to SPARC. Using Agisoft PhotoScan, Adam Barnes of SPARC extracted a dense point cloud (>8 million points) from the overlapping portions of the photos (Figure 2), georeferenced the model, and created orthophoto images (Figure 3) and a DEM. Ground control was based principally on stationary points such as power poles, and orthoimage pixels are accurate to ca. 1–1.5 m.

The orthophotos reveal distinct soil discolorations because the original photos were taken after the field had been disked, planted, and rained on, and only a few days after row crops (corn) had emerged. Soil discolorations indicate large-scale cultural features such as middens (dark colors) and a mound and possible geometric earthworks (light colors). The orthophoto also shows a series of narrow linear discolorations exactly 10 m apart that represent the paths created during the controlled surface collection that was underway at the time the photos were taken.

In addition to orthorectifying the 1990 photos, SPARC conducted the same process to create orthophoto images of Anderson's 1970s infrared photos. A June 1972 photo taken when most of the ground surface was visible depicts the dark stains of the Woodland occupation areas, a light spot that corresponds to the recorded mound location, and diffuse light-colored areas thought to be possible earthwork remnants (Figure 4).

High-Resolution Aerial-based Topographic Mapping

The DEM produced by orthophoto rectification has a 50-cm resolution, which is unfortunately not sufficiently sensitive to detect possible mound or earthwork features after they have been leveled and plowed. However, Iowa and Illinois statewide LiDAR coverage includes Gast Farm. Although it, too, is rarely able to detect leveled mounds, appropriate manipulation through vertical exaggeration might reveal such features.

William Whittaker (OSA) employed ArcScene to enhance the 2009 Iowa LiDAR data. At a resolution of ca. 5–10 cm, the most prominent features on the site are the parallel east-west crop rows (Figure 5a). Traces of what could be one or more mounds might appear on an oblique exaggeration (Figure 5b), but those could be an artifact of variation attributable to the LiDAR flight itself, as they appear to be positioned on one of a series of north-south "ridges" that extend across the field and that do not correlate with any topographic features.

Uncrewed Aerial System-based Mapping

Just as LiDAR is becoming a standard archaeological tool, so are Uncrewed Aerial Systems (i.e., unmanned aerial vehicles, or drones) and the array of digital mapping resources they offer. Mary De La Garza (OSA), a licensed UAS operator, directed two flights at Gast Farm in 2017. The first was on May 7, when corn stubble from the previous season still covered the site. The second flight was on August 25, when a solid growth of soybeans covered the field. Ms. De La Garza directed the UAS to fly the entire site in parallel transects at an altitude of ca. 100–120 m. Photogrammetry was recorded by a GoPro Hero camera, and thermal and visible light imagery was recorded by a FLIR Duo camera with an uncooled vanadium oxide microbolometer.

The May flight attempted to acquire photogrammetric data for generating additional high-precision elevation measurements and thermographic data to detect soil temperature (which can indicate traces of cultural features). Unfortunately, the dense stubble precluded collection of usable data. The August flight also did not collect usable soil temperature data because the bean crop completely obscured the ground surface. The thermography from that flight, which recorded vegetation growth characteristics that might reflect soil properties, is still being processed and interpreted.

The August flight did acquire useful photogrammetric data. We obtained a detailed rendering of the surface of the crop cover employing LAS, a binary format adopted to manage and standardize the way LiDAR data is organized and disseminated. Figure 6 depicts one or two faint rings of stunted soybean growth with interior “bullseyes” of enhanced growth. These slight elevation differences might represent mound outlines and central features. The location of the rings detected by the UAS flight matches well with mound locations recorded by the geophysical survey (see Mounds, below, and Wiewel and De Vore’s accompanying report). Furthermore, geophysical survey indicates low-magnetic anomalies (such as from subsoil) along mound circumferences and high-magnetic anomalies (as from topsoil) in mound centers. Crops thus would be expected to attain greater heights in topsoil-enriched mound centers and would grow more slowly along the subsoil-dominated mound edges, just as the UAS photogrammetry suggests.

Mounds

As noted earlier, previous work established that one mound had been present on the site. Former owner Dan Gast pointed out the location of the mound, which appears in the field as an area of lighter colored and coarser soil compared to its surroundings. Mr. Gast and others indicated the mound measured about 30 m in diameter and was ca. 3 m tall. Nobody mentioned the presence of other mounds.

Our own oblique photos and a variety of high-altitude vertical images suggested that geometric earthworks also might have been present at the site. Diffuse, light-colored soil occurs in some images as patterns we variously interpreted as rectilinear or octagonal (Whittaker and Green 2010). While Middle Woodland earthworks are relatively abundant in Ohio, they are quite rare in the Mississippi River valley. Verifying their presence at Gast Farm therefore became an important goal of the geophysical survey. As Wiewel and De Vore note in their accompanying report, the survey found no evidence of geometric earthworks.

However, the survey did reveal the unexpected presence of several additional circular mounds. Wiewel and De Vore discuss this discovery in the accompanying report. Here, we note that the mounds are oriented in a roughly north-south line with one or two outliers and are positioned between the Middle Woodland and Late Woodland communities (Figure 7). The platform pipes, copper axes, and mica found in the leveled mound demonstrate its Middle Woodland affiliation. The structural details reported by Wiewel and De Vore for several other mounds in the group suggest a similar affiliation for them as well. The 1990 controlled surface collection recovered several lamellar blades and at least one Snyders point from the mound area, consistent with Middle Woodland use.

Beloit College student Alexandra Flores virtually reconstructed the mounds. After determining each mound’s diameter from Wiewel and De Vore’s data, she estimated the original height of the mounds on the basis of dimensions of extant Woodland mounds in eastern Iowa (e.g., Beaubien 1953). After assigning the appropriate height to each mound, she virtually built them in 10-cm contour intervals (Figure 8). The estimated 2 m height of the largest mound is less than the ca. 3 m height mentioned by early observers, but no precise measurements were ever made of that mound and it is possible that its height was exaggerated in recollection. The estimated heights of the smaller mounds, which were never recorded, range between ca. 1 and 1.5 m.

The virtual reconstruction process, which used ArcGIS and its 3D Analyst toolbox, also permitted Ms. Flores to estimate that the surface area covered by mounds totaled ca. 439 m^2 and the volume of mound fill amounted to ca. 833 m^3. This information can be helpful in determining the origin of the light-colored surface soil once thought to possibly represent geometric earthworks. If mound fill was light colored, as we know the largest mound's was, and if it had been spread across the field primarily in the common directions of tilling (i.e., the cardinal directions), the resulting light-colored soil would appear in linear bands mostly east and south of the mound locations. Spreading 833 m^3 of mound fill to a depth of, say, 1 m would cover 527 m^2. Spreading the fill to a more realistic depth of, say, 0.25 m would cover 2.1 ha, which is a fair estimate of the ground covered by the broad, light-colored bands. It is thus fair to suggest that the "earthwork" features resulted from the redeposition of mound fill, most likely in the late 19th or early 20th century, when horse-drawn scrapers could easily manage leveling the small mounds. Fortunately the large mound was spared into the 20th century.

Although the mounds are situated between the Middle and Late Woodland communities, several lines of evidence suggest the mounds are of Middle Woodland affiliation. In addition to the points noted above, Late Woodland burials at Gast Farm have been documented within the community itself (Lillie 2002) and were probably also deposited in the small mounds once located on the adjacent bluff tops (Gass 1883; Whittaker 2014). Also, a large Middle Woodland site located on an alluvial fan 28 km south of Gast Farm is associated with a similarly situated group of seven mounds that have produced Middle Woodland diagnostics (Scholtz 1960; Straffin 1971).

Habitation Features

In addition to the mounds, Wiewel and De Vore's magnetic survey located two clusters of anomalies identified as cultural features (see accompanying report). The locations of the anomalies match the distribution of diagnostic Middle Woodland and Late Woodland ceramics in the eastern and western portions of the site, respectively, as documented by the 1990-1991 controlled surface collection (Figure 9). This concordance permits us to identify the cultural affiliation of the feature clusters and the structure of the communities they represent. Wiewel and De Vore's report discusses community layouts. The Dating section (below) addresses Middle Woodland community structure and function in particular.

As noted above, field school excavations in 1991-1994 exposed ca. 1 percent of the sub-plow zone deposits in the Middle and Late Woodland communities. Those excavations recorded 19 features in the Middle Woodland community and 137 in the Late Woodland community. Most of the Middle Woodland features were completely excavated, but portions of many Late Woodland features were left unexcavated if they extended into unopened units. We know the approximate shapes, dimensions, and contents of those unexcavated portions on the basis of the excavated portions. We therefore thought that analysis of relationships between unexcavated feature segments and associated magnetic data might help in understanding the nature of features indicated by anomalies in unexcavated portions of the site. Because features in the Middle Woodland community had been more thoroughly excavated and were generally smaller, less distinct, and more widely scattered than those in the Late Woodland village, we focused on Late Woodland features in addressing this question.

We compared the magnetic anomalies considered to be large prehistoric features (positive magnetic monopole anomalies >2.5nT and $\geq 0.25m^2$) to features documented by excavation in the Late Woodland area. Figure 10 depicts the five 10 x 10-m excavation blocks and the units excavated within each block in relation to those anomalies. No anomalies are associated with the West, Center, and East blocks. The North Block has two anomalies at its edges, and the South Block has two anomalies within it and four anomalies at its edges. Both of the North Block anomalies appears to be just outside of the excavated areas, so no relationship to features can be determined. Three or four of the South Block features seem to correlate with significant anomalies. However, before interpreting relationships between features and magnetic anomalies, we need to expand the range of anomalies under consideration to include positive monopoles <2.5nT. This work is ongoing, as is analysis of relationships between backfilled features and magnetic anomalies.

Dating

Prior to 2016, we had obtained only three radiocarbon dates on the Middle Woodland component. As the geophysical survey data came in and the apparent oval-plaza structure of that community appeared to take shape, it became clear that more dates were needed. This is because the layout and large size of the residential area (see Wiewel and De Vore's accompanying report) have no analogue among known Havana-Hopewell sites in the Midwest. The question arose whether the component represented a single, short- or long-term occupation, or perhaps periodically repeated occupations that ended up appearing to be a larger, planned community.

Selection of additional samples for dating focused on organic material from feature contexts with associated Middle Woodland diagnostics. No additional dating was conducted for the Late Woodland community because a suite of 12 dates was sufficient to indicate occupation of that village during a relatively short time span between ca. AD 350 and 500, with a possible second occupation slightly later (Benn and Green 2000).

We obtained seven additional dates associated with the Middle Woodland component, plus one from a nearby Middle Woodland camp (the Griffin site, 13LA101), and one that apparently belongs to the immediately preceding Early Woodland (Liverpool) occupation (Table 1; Figure 11). Samples consisted of plant remains (annuals such as nutshell whenever possible) or, in one case, bone collagen. Paired samples indicate concordance between labs and sample types. However, two additional assays—on calcined bone—

returned ages 350–400 radiocarbon years later than nutshell from the same contexts, so they were excluded from further consideration. While calcined bone produces reliable dates in some circumstances (Chatters et al. 2017), such was not the case here.

The Gast Farm Middle Woodland dates indicate an occupation or several occupations dating between ca. cal. 50 B.C. and A.D. 250. This range is consistent with age determinations and estimates for Havana assemblages in the central Illinois River valley type locality and in the lower Illinois River valley and American Bottom regions. Further work is needed to determine which habitation models (continuous short- or long-term occupation, or periodic abandonment and reoccupation) are consistent with the spread of dates. Bayesian analysis and more detailed ceramic studies can address this question. On the basis of botanical and faunal data, occupation occurred mostly during the warm seasons (Dunne 2002; Neverett 2001). Exotic materials indicate interaction with other Hopewell-related groups, and construction of mounds adjacent to the habitation area suggests the inhabitants engaged in mortuary rituals on a periodic basis. Knowing these aspects of the occupation, perhaps the most parsimonious model at this point for understanding site layout is that the habitation area served as a site for periodic regional gatherings during much of the Havana-Hopewell episode and that residential units may have arranged themselves in an oval surrounding a central open area.

Discussion and Conclusion

This project combined GIS development, aerial imagery analysis, and geophysical survey to address several questions regarding prehistoric Woodland communities in southeast Iowa. Middle and Late Woodland communities at Gast Farm had been identified through surface collections and small-scale excavations, but overall layouts were unknown (for the Middle Woodland component) or conjectured (for the Late Woodland). The presence of one mound had been documented, and a geometric earthwork was thought to be present as well. Defining community organization, locating any subsurface traces of the mound, and determining the reality of the suspected earthwork constituted key research objectives.

As detailed above and in the accompanying report by Wiewel and De Vore, the project identified the Middle Woodland (Havana-Hopewell) community plan as an oval-shaped distribution of features surrounding an open space. Radiocarbon dating and other evidence suggest habitation may have been episodic, with the site serving as a repeatedly occupied Havana-Hopewell aggregation center. The project also confirmed the suspected circular or oval community plan of the Late Woodland (Weaver) village. Weaver occupation apparently was more intensive but was of shorter overall duration.

We recovered no evidence for geometric earthworks, but the magnetic survey discovered six mounds in addition to the previously known mound. Drone-based photogrammetry also revealed possible mound traces. Estimation of the likely original fill volume of the mounds led to the hypothesis that the surface soil discolorations thought to represent earthworks instead derive from displaced mound fill.

In addition to accomplishing the above substantive results, this project demonstrated the viability of magnetic gradiometry for identifying Woodland residential and mortuary features in Mississippi Valley alluvial fans. It also incorporated legacy oblique aerial photography in a georeferenced GIS, indicated the potential of drone-based photogrammetry in identifying cultural features beneath crop cover, and modeled the virtual reconstruction of leveled mounds.

Future research at Gast Farm can take advantage of the GIS to study site structure in greater detail. Correlating magnetic data and recorded but unexcavated features holds promise, as does continued processing and interpretation of the UAS-derived photogrammetry and thermography. In terms of additional fieldwork, subsurface features may remain intact at the mound locations, so further noninvasive investigation of those loci is a priority. In the long run, ground-truthing of other magnetic anomalies also should be undertaken to refine our understanding of community structure.

Dissemination and Curation

During the project period, participants gave progress reports in public forums in Columbus Junction, Council Bluffs, and Iowa City, Iowa; Albany and Rock Island, Illinois, and Beloit, Wisconsin. Professional papers and posters were presented at the Midwest Archaeological Conference (Iowa City, IA and Indianapolis, IN), and a poster will be presented at the 2018 Society for American Archaeology annual meeting (Washington, D.C.). A journal article on the Middle Woodland community and its associated mounds is in preparation. Other publications will be prepared in the future.

Project data are currently housed at the three principal partnering organizations: the Midwest Archeological Center, National Park Service; the Office of the State Archaeologist, University of Iowa; and the Logan Museum of Anthropology, Beloit College. The Office of the State Archaeologist, University of Iowa will serve as the permanent repository for project data.

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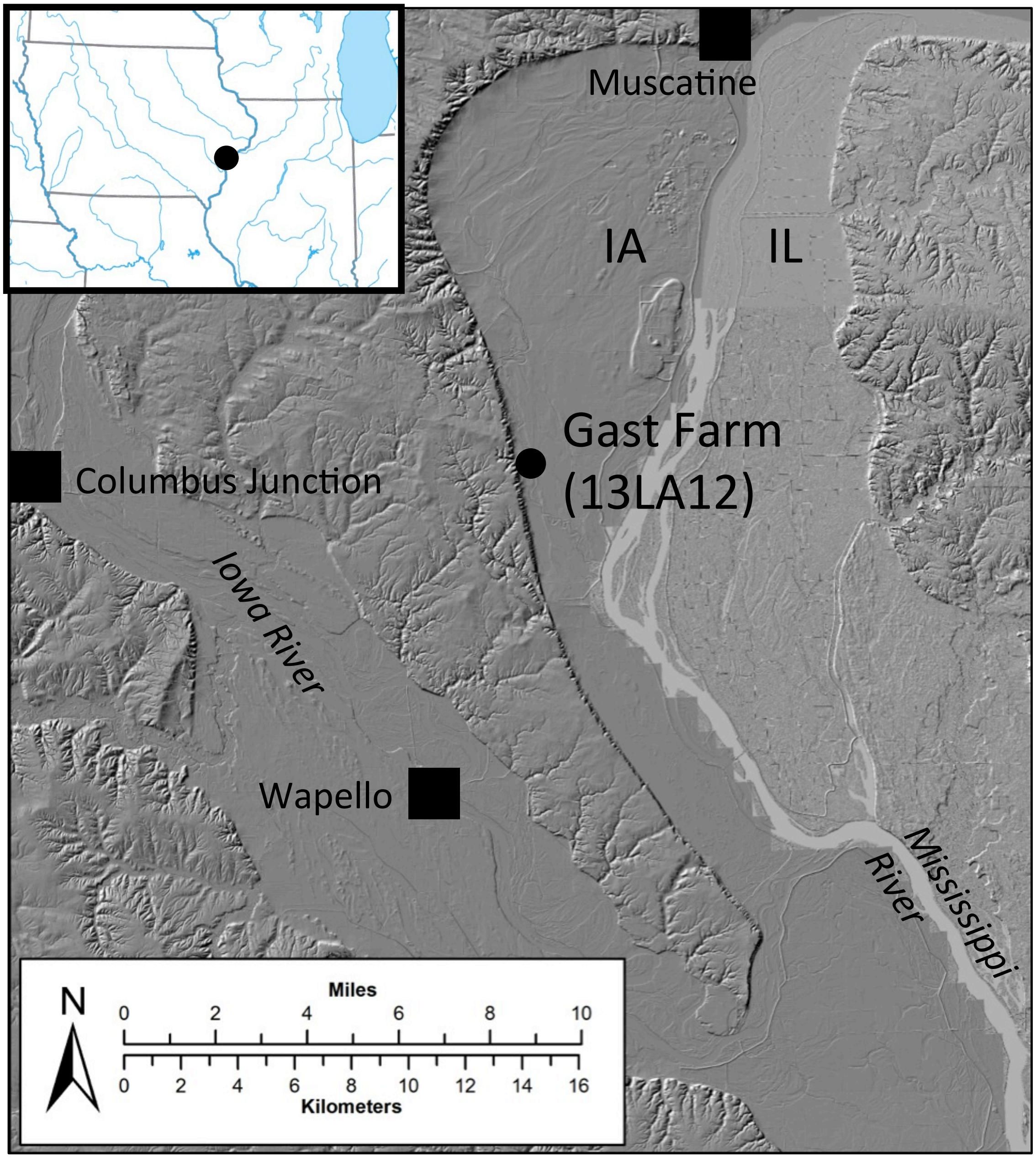


Figure 1. Gast Farm location map, showing surface hydrology, relief, and modern municipalities. (Base maps: Illinois and Iowa statewide LiDAR.)

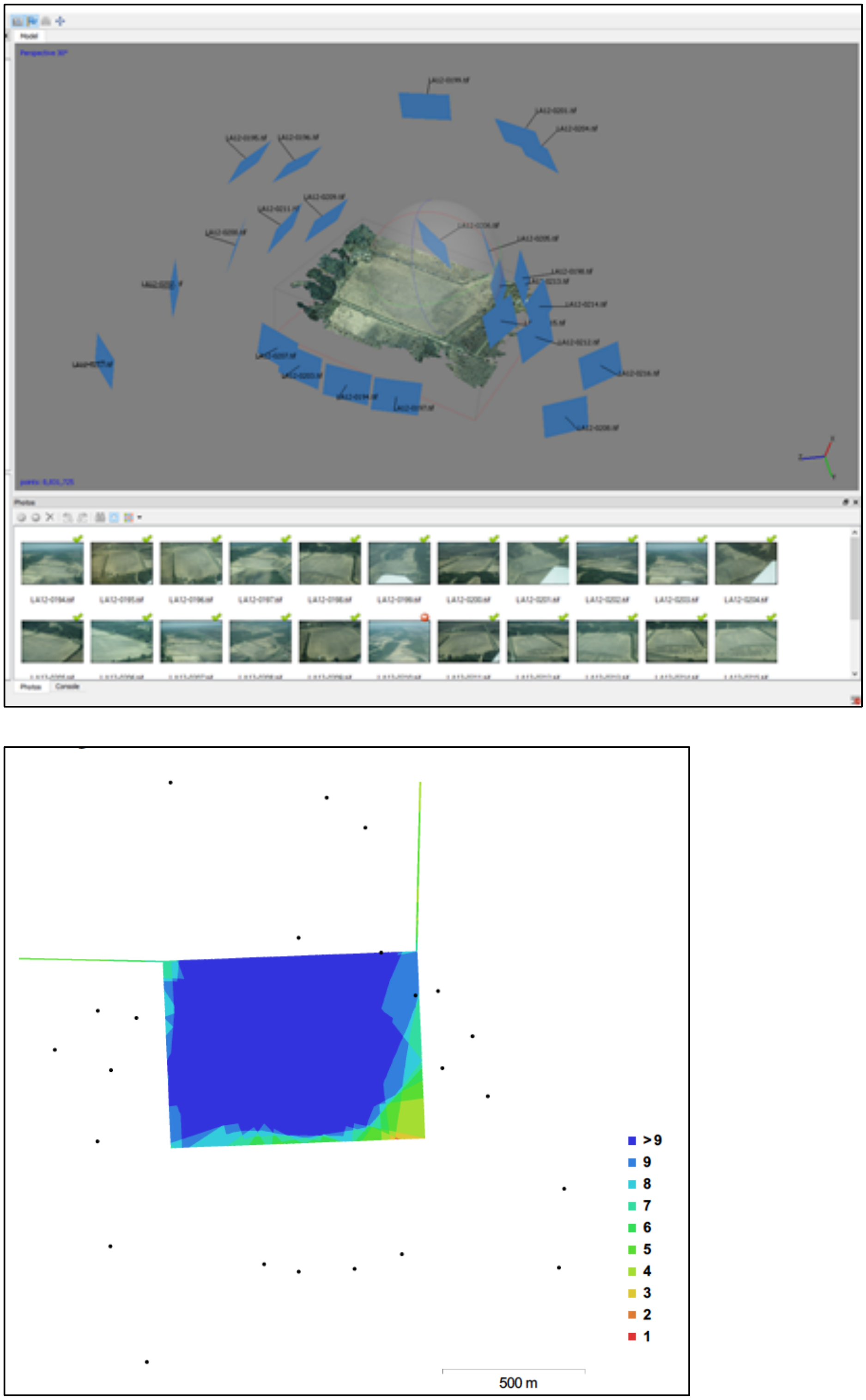


Figure 2. Agisoft PhotoScan model showing ortho-rectification of 1990 oblique aerial imagery (top) and overlapping portions of original images (bottom) (from Adam Barnes, SPARC).

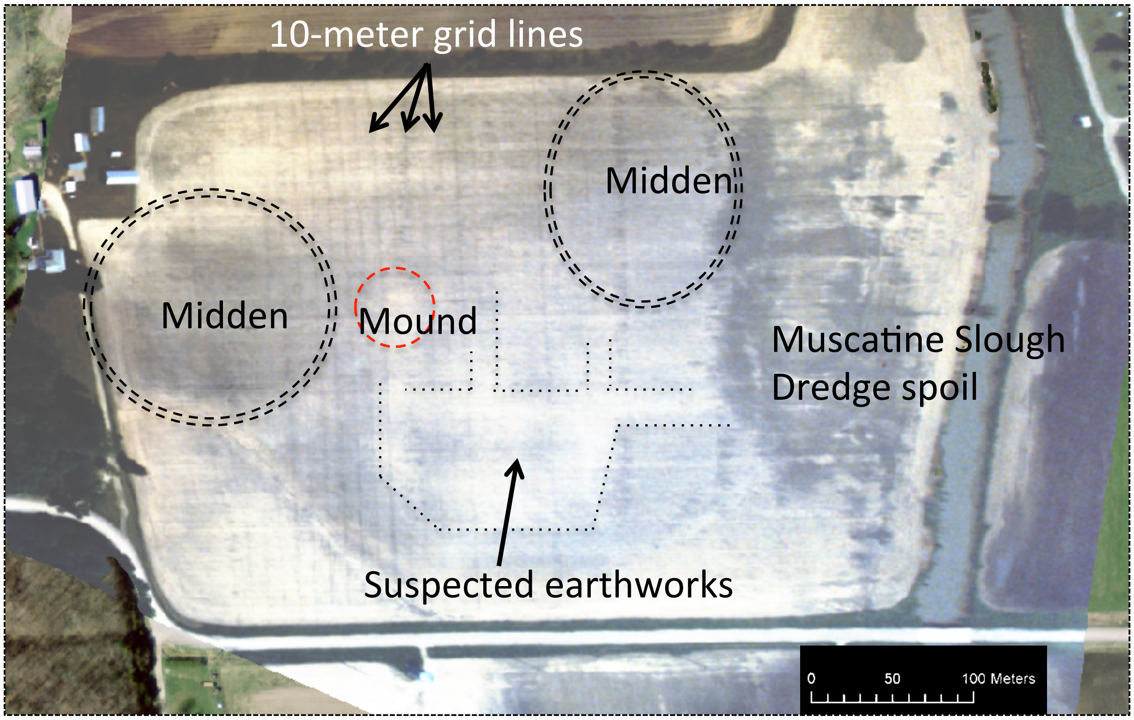


Figure 3. Orthorectified image built from 1990 oblique aerial imagery (from Adam Barnes, SPARC), with cultural features indicated.

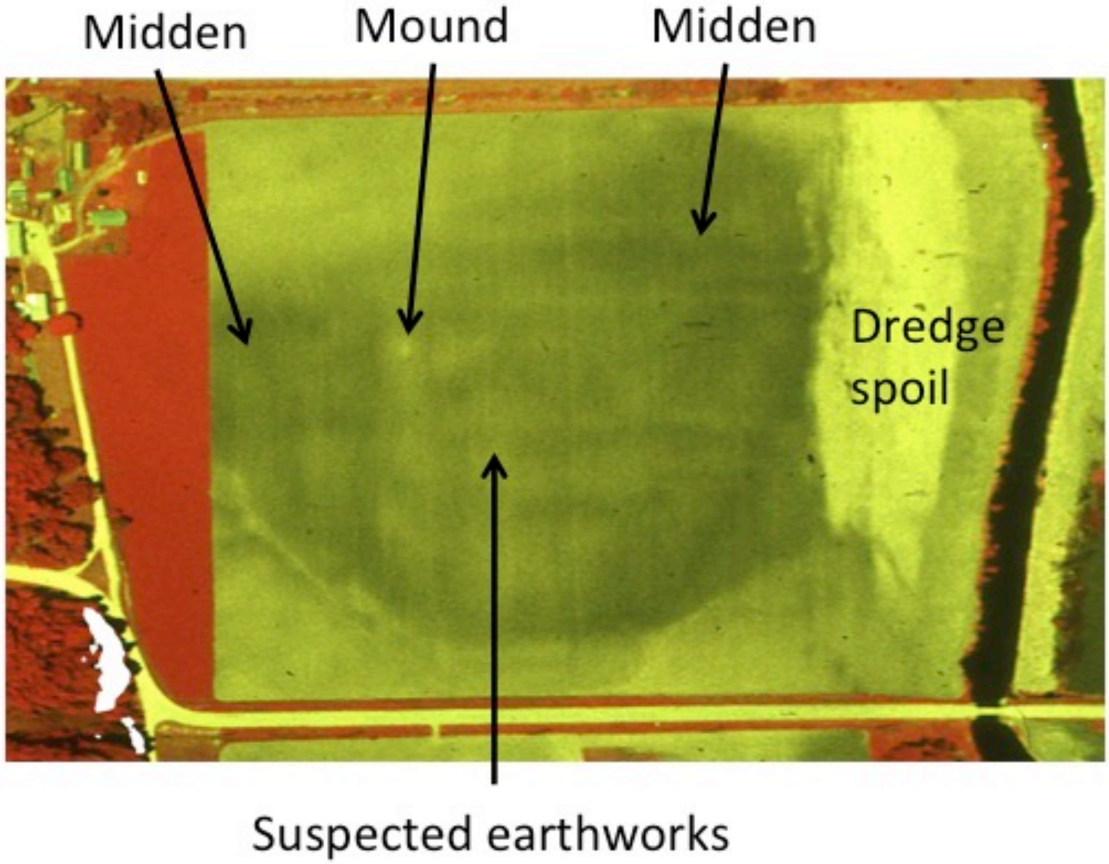
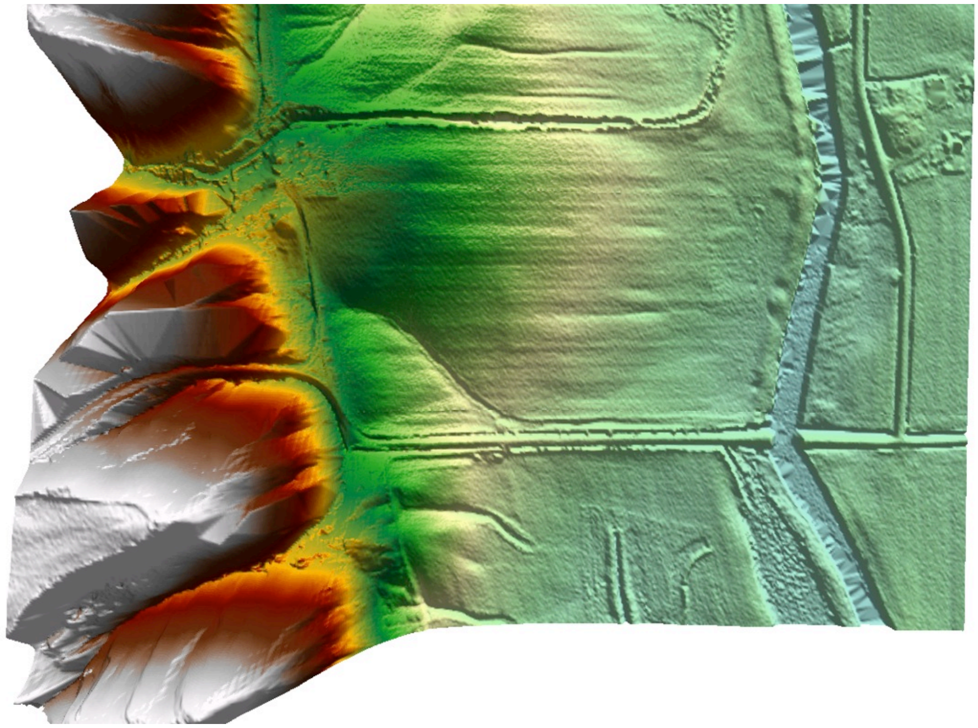


Figure 4. Orthorectified image built from June 1972 oblique infrared aerial photo (from Adam Barnes, SPARC; original photo from Ferrel Anderson), with cultural features indicated.



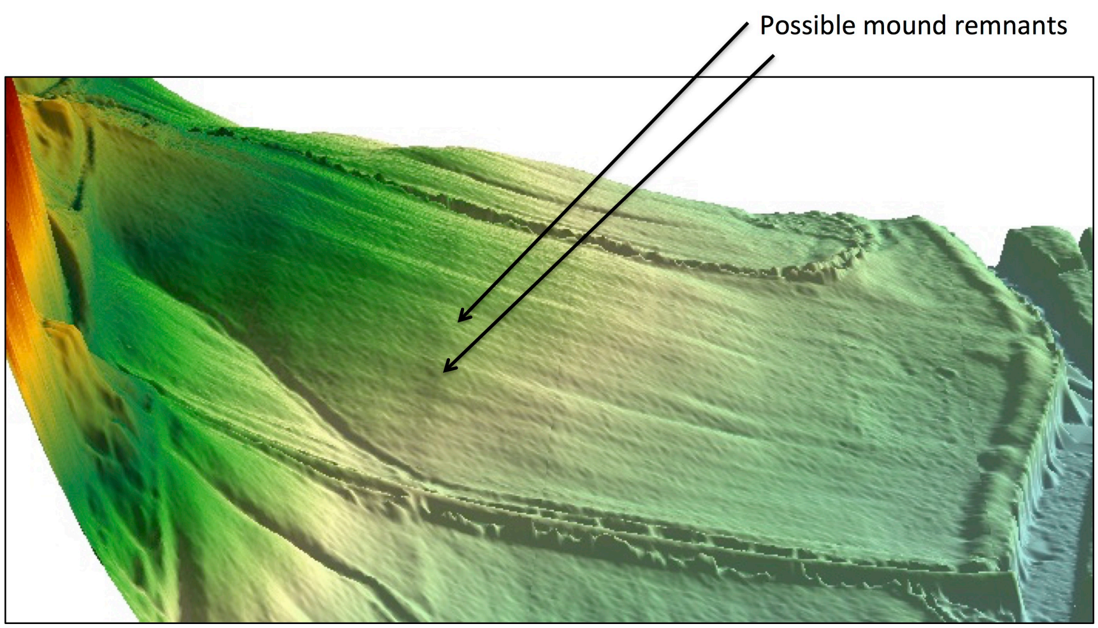


Figure 5.
a. (Top) Exaggerated vertical LiDAR image with ArcScene enhancement (from William Whittaker, OSA).
b. (Bottom) Exaggerated oblique LiDAR image with ArcScene enhancement (from William Whittaker, OSA).

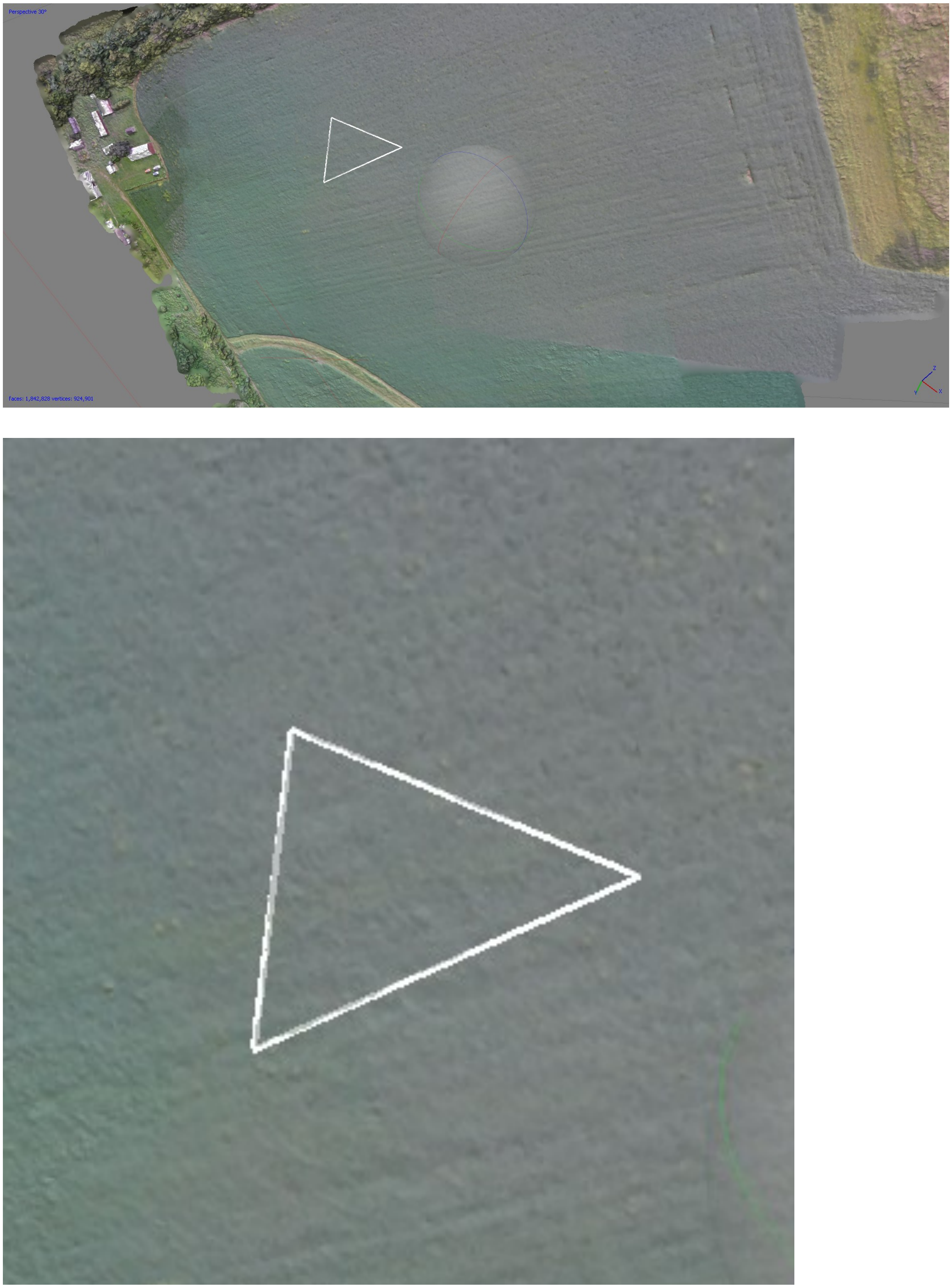


Figure 6. Unmanned Aerial System composite image from August 25, 2017 flight; note possible mound outlines inside white triangle. Orb feature is a rotation tool for 3D objects (from Mary De La Garza, OSA).

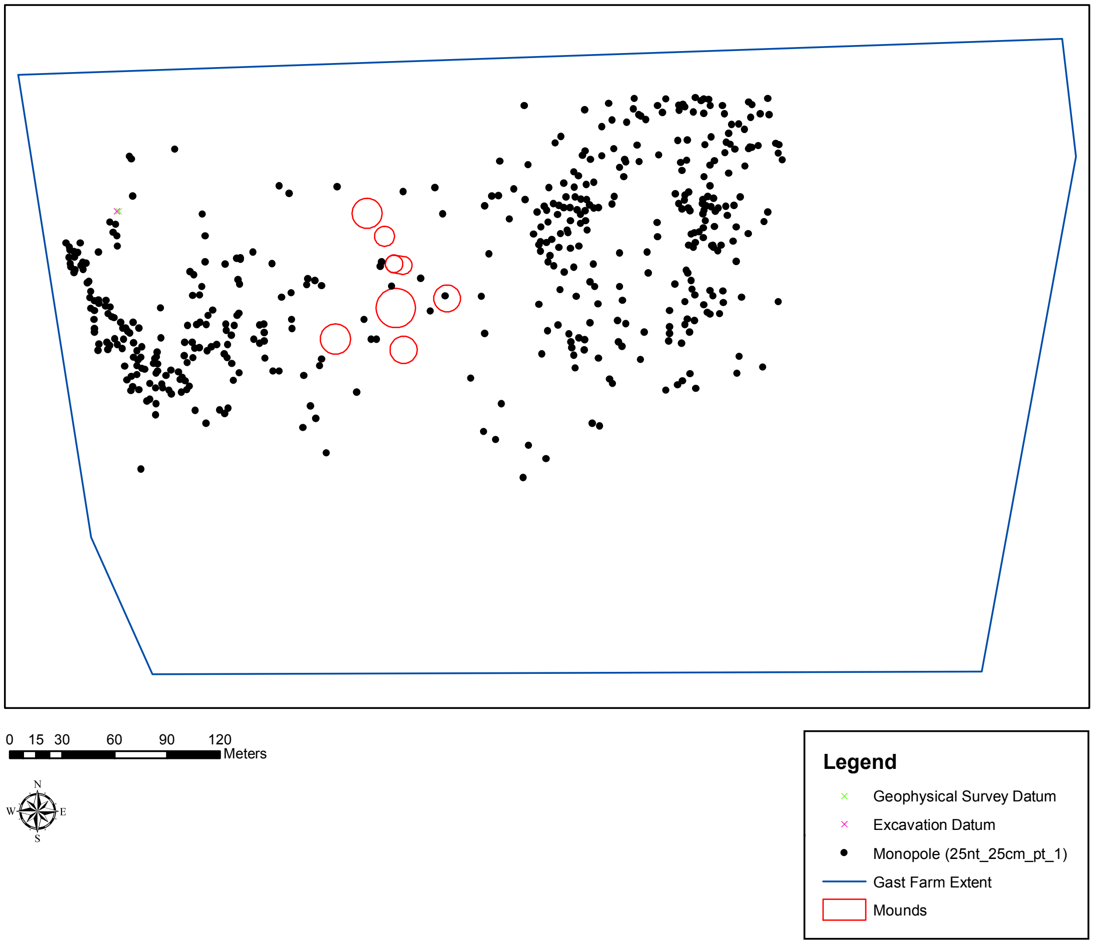


Figure 7. Mound locations (red circles) as determined by geophysical survey, in relation to cultural features indicated by positive magnetic monopole anomalies >2.5nT and ≥0.25m^2 (black dots) (from Alexandra Flores, Beloit College, based on data from Wiewel and De Vore (accompanying report).

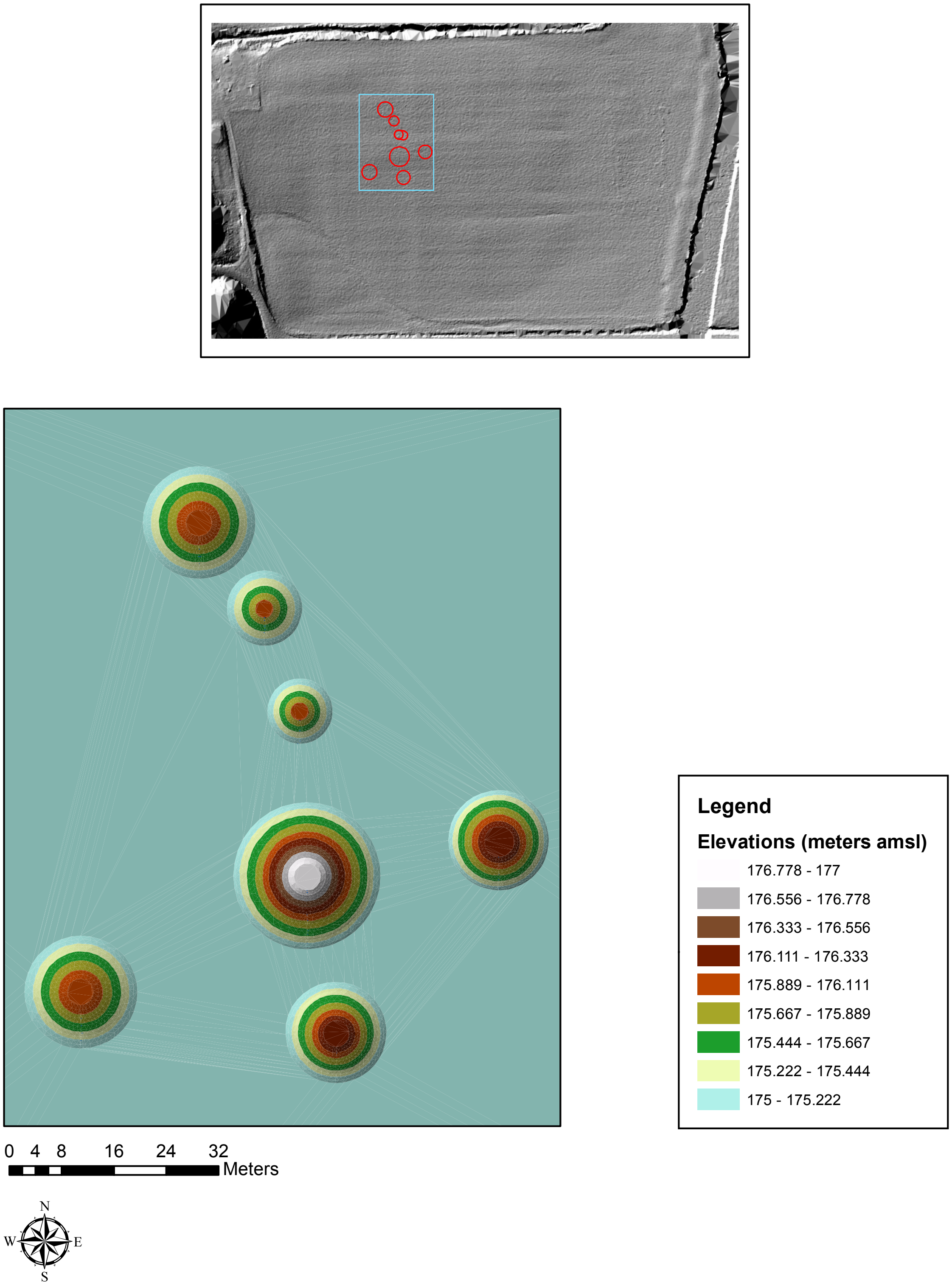
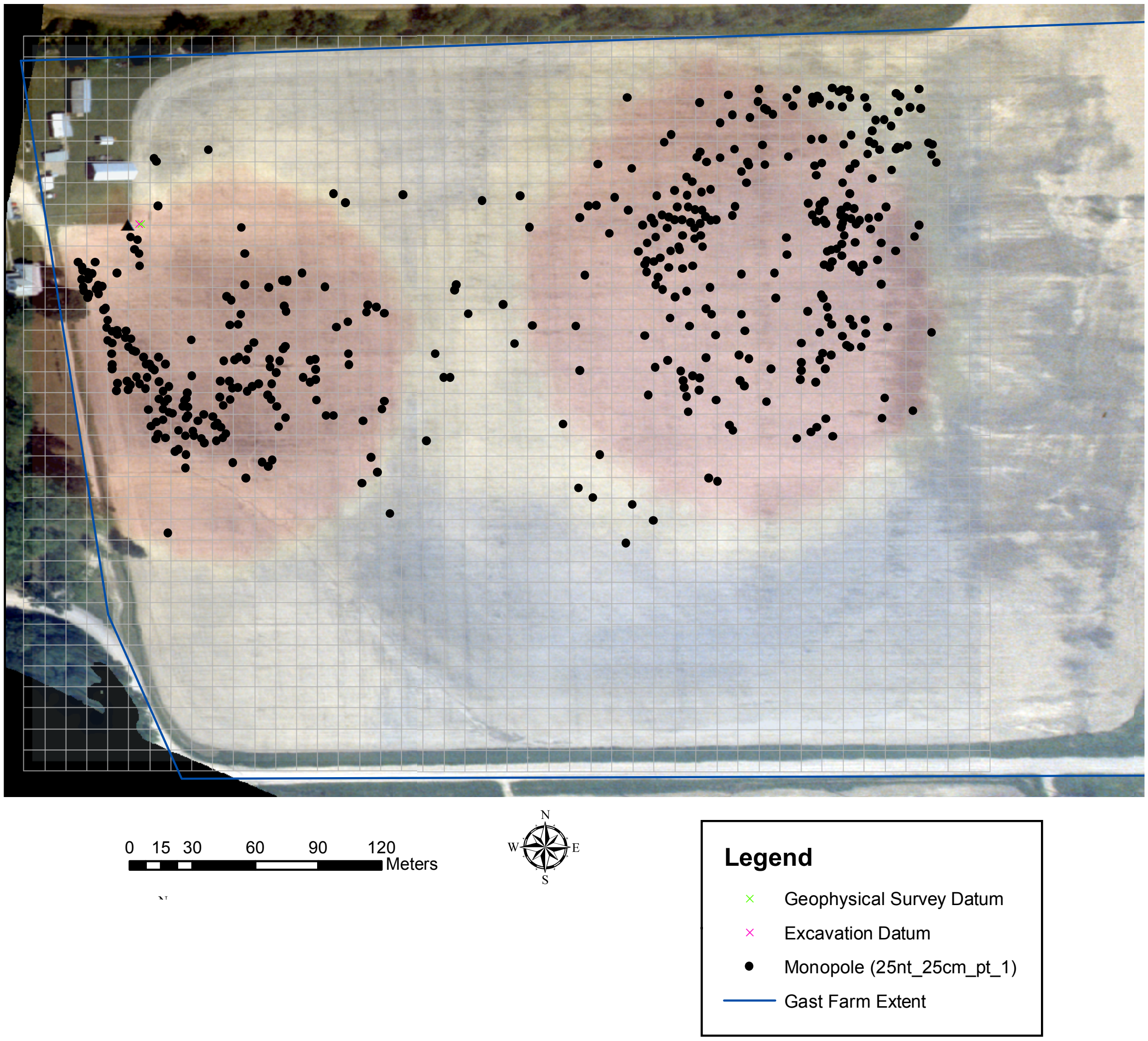


Figure 8. Estimates of original mound height and shape. Contour interval: 10 cm (from Alexandra Flores, Beloit College).



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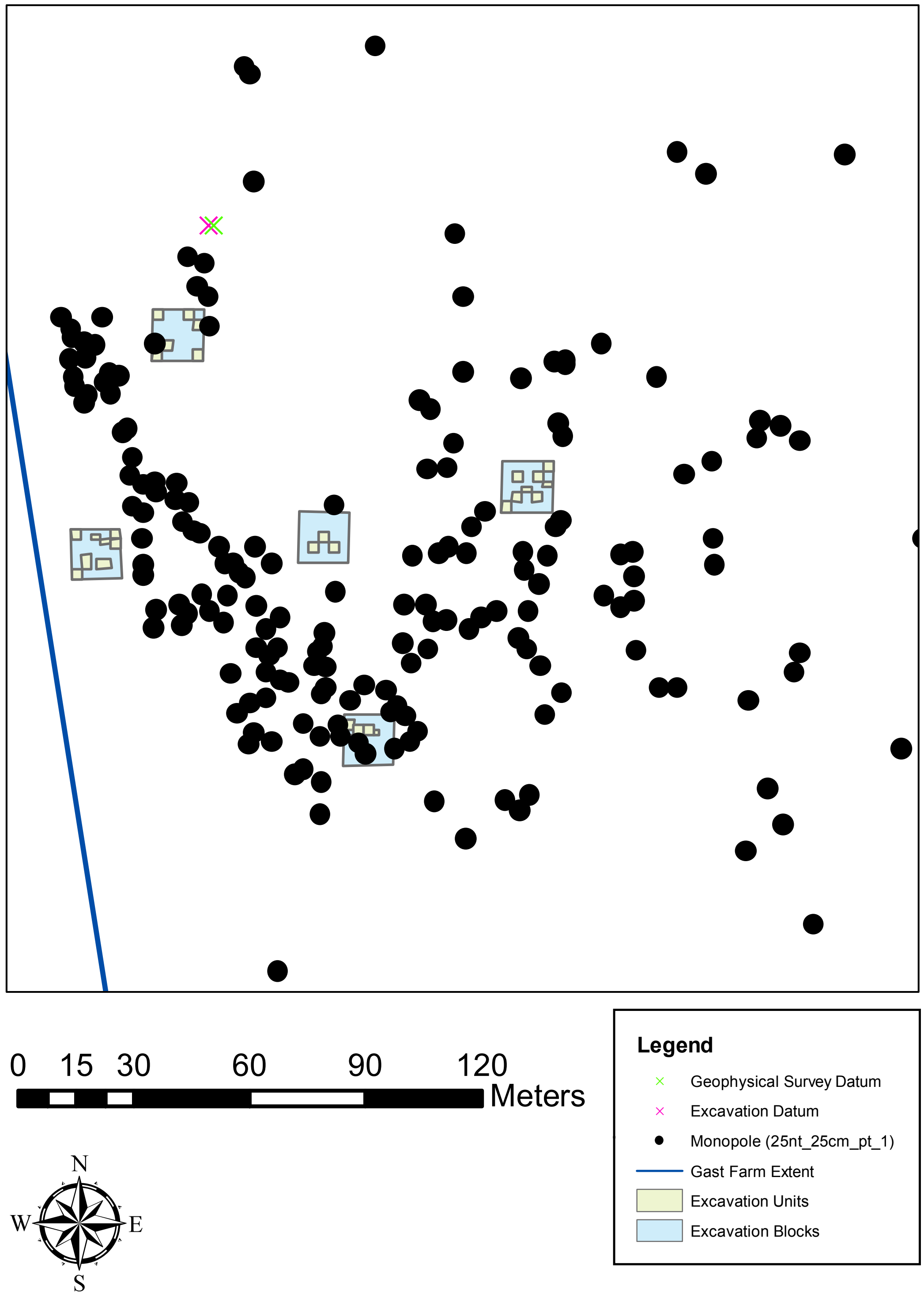

Figure 10. Excavation blocks in the Late Woodland community in relation to magnetic survey-defined cultural features (positive magnetic monopole anomalies >2.5nT and $\geq 0.25m^2$).

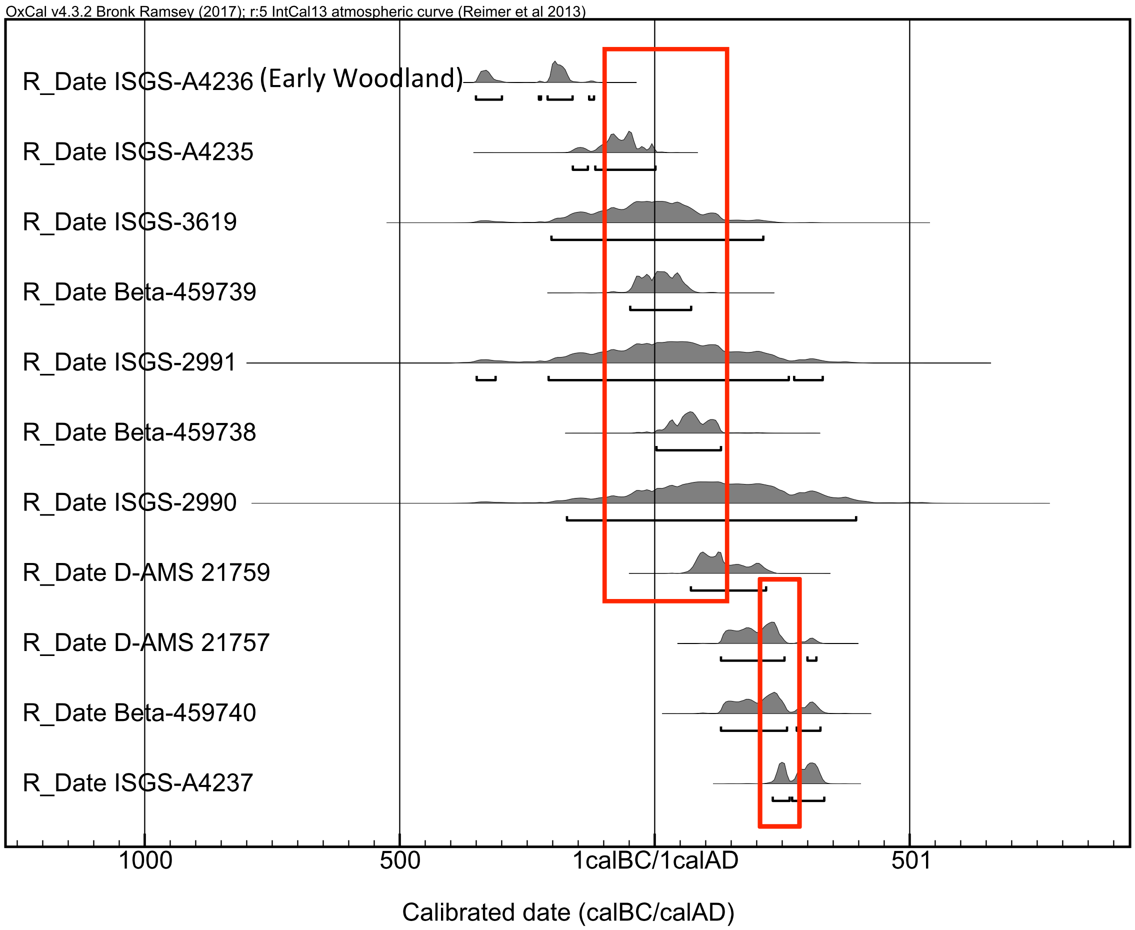

Figure 11. Radiocarbon dates for the Middle Woodland component.

Table 1. Radiocarbon dates for the Middle Woodland component (arranged by age in ascending order).

Lab Number	Sample Number	Provenience	Material	d13C	Conventional Age	2 Sigma Calibration
ISGS-A4237	13LA12/E297A	Feature 20	Charred hazelnut shell	-26.2	1765 +/- 15 BP	Cal AD 235-265 and 270-330
Beta-459740	13LA12/E293B	Feature 20	Charred walnut shell	-28.1	1800 +/- 30 BP	Cal AD 130-260 and Cal AD 280-325
D-AMS 21757	13LA12/E413B	Feature 4	Charred hazelnut shell	-21.1	1808 +/- 23 BP	Cal AD 130-255 and Cal AD 300-320
D-AMS 21759	13LA12/E206	Feature 21	Bone (collagen)	-19.3	1876 +/- 26 BP	Cal AD 70-220
ISGS-2990	13LA12/FH92-21	Feature 21	90% charred wood, 10% hickory and hazelnut shell	-25.0	1890 +/- 120 BP	Cal BC 170 - Cal AD 400
ISGS-3341	13LA101	58E, 2.5 m b.s.	60% charred wood, 40% charred hickory and walnut shells	-25.7	1910 +/- 70 BP	Cal BC 55 - Cal AD 255
Beta-459738	13LA12/E297B	Feature 13	Charred Juglandaceae shell	-24.4	1930 +/- 30 BP	Cal AD 5 to 130
ISGS-2991	13LA12/FH92-24	Feature 24	90% charred wood, 10% Juglandaceae shell	-25.8	1960 +/- 110 BP	Cal BC 210 - Cal AD 265
Beta-459739	13LA12/E296A	Feature 19, S 1/2	Charred Juglandaceae and hazelnut shell	-25.3	1990 +/- 30 BP	Cal BC 45 to AD 70
ISGS-3619	13LA12/FH91-1	Feature 1	Charred wood, grass stems hazelnut shell	-25.9	2000 +/- 80 BP	Cal BC 200 - Cal AD 180
ISGS-A4235	13LA12/E295A	Feature 16 N 1/2	Charred hazelnut shell	-27.9	2055 +/- 20 BP	Cal BC 160-135 and 115-0
ISGS-A4236	13LA12/E410A	Feature 3	Charred Juglandaceae shell	-26.8	2115 +/- 15 BP	Cal BC 195-90

Magnetic Gradiometry Survey Results at Gast Farm (13LA12), a Multicomponent Woodland Site in Louisa County, Iowa

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ABSTRACT

In collaboration with Beloit College and the Office of the State Archaeologist (University of Iowa), archeologists Steven De Vore and Adam Wiewel from the National Park Service, Midwest Archeological Center performed an extensive magnetic gradiometry survey at Gast Farm (13LA12) in November 2016. The multicomponent site is located in southeastern Iowa along the western margin of the Mississippi River valley. Systematic surface collections during the 1990s indicated distinct residential areas defined particularly well by ceramics, including a Middle Woodland community associated with Havana sherds and an abundance of Weaver pottery at a Late Woodland settlement. Soil marks visible in aerial photographs and thermal infrared images further delineated the circular form and central plaza of the Late Woodland village. Aerial imagery also reveals the locations of a mound leveled during the 1950s and a possible circular or polygonal earthwork, neither of which exhibit definite topographic expressions.

The magnetic gradiometry survey at Gast Farm was carried out with the general goal of corroborating these findings. More specifically, the investigation was meant to definitively identify the settlement layouts of both residential areas, document subsurface features, and determine the nature and extent of the burial and ceremonial complex. During a two-week period, 216 complete and one partial 20-m-x-20-m grids, totaling an area of 86,400 m^2 (21.35 acres), were surveyed with two instruments operated simultaneously.

The survey offers new insights into this complex site. Among the findings, hundreds of magnetic anomalies that likely represent hearths, earth ovens, and pits were identified. These probable features are clustered most densely in two locations, the areas that have been identified as separate Woodland habitations. Both communities are roughly circular in shape, and based on an absence of anomalies, appear to have plazas. In other words, the Middle Woodland community exhibits the same settlement plan that is characteristic of Late Woodland villages, with dwellings occupying a circular space surrounding a central plaza. No additional evidence of an earthwork was discovered during the magnetic survey, although alternating rings of positive and negative anomalies indicate the presence of not one, but several mounds. Moreover, elements of the mounds’ construction and use, including the presence of centralized tombs, remain apparent despite many decades of cultivation.

ACKNOWLEDGMENTS

Several individuals contributed to the success of the magnetic gradiometry survey at Gast Farm and the production of this report. William Green, Director of the Logan Museum of Anthropology at Beloit College, and John Doershuk, Director of the Office of the State Archaeologist (OSA, University of Iowa), played fundamental roles in planning and carrying out the project. Vergil Noble from the National Park Service, Midwest Archeological Center (MWAC) contributed additional funding from the National Historic Landmarks Program and provided valuable comments and edits to the manuscript draft. Likewise, Allan Weber and Jeff Larson, Visual Information Specialists from MWAC, offered additional edits and prepared the draft for publication.

The landowners, Linda Gast and Jack Wilson, kindly allowed us to spend two weeks at Gast Farm in November 2016. Bryan Hoben, who farms the property, generously mowed a large section of the field during the project to facilitate the geophysical survey. Besides Bill Green, Glenne Tietzer, a 2016 graduate of Beloit College, and Brianna Hoffman, a field technician for the OSA, provided invaluable field support. Also aiding the fieldwork were Linda Forman, Bill's wife; Michael Perry, a retired archeologist for the OSA; and Julie Plummer. We greatly appreciate their help.

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INTRODUCTION

Between November 7 and November 17, 2016, National Park Service, Midwest Archeological Center (MWAC) archeologists Steven De Vore and Adam Wiewel carried out a magnetic gradiometry survey at the Gast Farm (13LA12) site in Louisa County, Iowa. Prior to our investigation, personnel with the University of Iowa and Iowa Archeological Society had conducted systematic surface collections and test excavations, which indicated two concentrations of Middle and Late Woodland artifacts and features associated with distinct communities that date to the earliest centuries of the first millennium A.D.

The survey at Gast Farm was performed with the general intention of supporting these results. More specific goals included: 1) documenting and clarifying the distribution of likely subsurface archeological features such as hearths, earth ovens, and pits; 2) identifying architectural features such as houses associated with either the Middle or Late Woodland occupations; 3) defining the settlement plans of both residential areas more precisely; and 4) improving our understanding of the components of a mortuary-ceremonial complex, which includes a mound and possible earthwork.

In this report, we provide background information concerning previous work at Gast Farm. Additionally, we describe magnetic gradiometry as well as geophysical survey and data-processing methods. Finally, we discuss the findings of the survey and interpret the results in the context of these previous investigations.

Gast Farm (13LA12)

Gast Farm is an approximately 13-ha archeological site with multiple Woodland components located at the base of the bluff that forms the western margin of the Mississippi River valley in southeastern Iowa (Figure 1). Extensive systematic surface collections and block excavations by the University of Iowa and Iowa Archeological Society during the early 1990s revealed two significant residential components (Green et al. 2016). A Middle Woodland Havana-Hopewell occupation, located in the east half of a cultivated field adjacent to Muscatine Slough, was dated to ca. 50 B.C.–A.D. 100 (Green et al. 2016; Whelan and Green 1996). A spatial analysis of Havana ceramics recovered by surface collection shows a statistically significant cluster of sherds in a 120-m-x-80-m oval-shaped area (Green et al. 2016; Figure 2).

Aerial photographs and thermal infrared images reveal the location of a contemporaneous burial and ceremonial complex, including a large mound toward the center of the site that was leveled in the 1950s (Green et al. 2016; Whittaker and Green 2010). The mound's topographic expression has been obscured by decades of ground-disturbing cultivation activities (Figure 2). Still, the location of this feature is indicated by an area of contrasting light-colored soils along the northwest edge of a possible geometric earthwork, the outline of which is also made evident by soil marks (Green et al. 2016; Whittaker and Green 2010). The earthwork exhibits a circular or polygonal perimeter approximately 175 m in diameter with a linear embankment extending to the east.

A Late Woodland Weaver phase community dated to ca. A.D. 350–450 is located to the west atop an alluvial fan that slopes across the cultivated field (Green et al. 2016; Figures 2 and 3). Its general circular form, approximately 120 m in diameter, is apparent in aerial photographs due to relatively darker soils associated with midden deposits (Green et al. 2016). Such patterning—referred to as "ring midden"—is common among Weaver phase and contemporaneous Woodland sites where the settlement organization is characterized by dwellings arranged in a circle or oval around an open plaza (Esarey et al. 1984; Freeman 1969; Green 1992). At Gast Farm, soil marks associated with the Late Woodland community are paralleled by a statistically significant cluster of Weaver ceramic sherds (Green et al. 2016; Weitzel 1992). Block excavations within both localities also revealed many intact subsurface features (Green et al. 2016; Neverett and Whelan 1996), a significant finding given the site's recent history of plowing and a good indicator of the potential success of magnetic prospection techniques.

METHODS

While soil marks and sherd distributions indicate the general forms of the Woodland settlements, information about subsurface archeological features is limited to relatively small block excavations in both locations. In this situation, geophysical surveys offer an independent means of corroborating previous findings and can provide primary data concerning spatial patterns and relationships among subsurface features at Gast Farm. In other words, wide-area geophysical surveys can yield a more comprehensive view of site content, feature distribution and site organization, and spatial relationships (Kvamme 2003). Furthermore, multi-instrument investigations are preferable because different devices provide unique and complementary information (Kvamme 2006a, 2007; Kvamme et al. 2006). However, the investigation at Gast Farm was limited to a magnetometer survey due to the method's sensitivity to magnetic variations resulting from specific anticipated features like hearths, earth ovens, and pits as well as its relatively rapid measurement rate.

Survey Area

Most geophysical instruments, including magnetometers, require data to be acquired systematically in areas composed of equally sized grids (Kvamme 2006b:214). To cover the cultivated field at Gast Farm, 297 complete 20-m-x-20-m grids were created in an area of 118,800 m^2 (29.37 acres) with dimensions of 300 m north–south and 460 m east–west (Figure 4). Ultimately, a smaller area with 216 complete and one partial grids (86,400 m^2 or 21.35 acres) was surveyed during the two-week investigation. Still, the survey covered all but a small portion of the Late Woodland settlement to the west and the southernmost part of the possible earthwork.

To create the survey grid a datum was placed at the east end of a fence, the approximate location of the datum used during the 1990s fieldwork, along the northwest edge of the field (Figure 4). A backsight point was then positioned about 8 m away along the same fence with a Ushikata TRACON S-25 surveying compass at an azimuth of 270 degrees (Figures 4 and 5). A Trimble 5500+ robotic total station was then placed on the datum, and its stakeout function was used to place grid corners at 20-m intervals across the cultivated field (Figure 5). Wooden hub stakes and fiberglass pin flags were used to mark all grid corners. Their locations were subsequently recorded with a Trimble Geo 7X unit and Tornado dual frequency Global Navigation Satellite System (GNSS) antenna using the NAD 1983 UTM Zone 15N coordinate system (Figure 6).

Data collection occurred in a systematic, block-by-block manner throughout the 20-m-x-20-m grid units. Twenty-meter-long survey ropes were placed along the east and west baselines of each grid, and similar ropes were placed within each grid at 2-m intervals to mark survey transects (Figure 7). The ropes, which are labeled at 0.5 m increments, enable instrument operators to survey at a consistent metronome-guided pace and ensure the instrument's correct spatial location along and between transects. Survey traverses were separated by 0.5 m, and eight samples per meter were recorded for a total of 16 measurements per square meter.

Magnetism and Instrumentation

Magnetometry is a passive geophysical method (Aspinall et al. 2009:31-41; Kvamme 2006b). Unlike active instruments that generate or transmit a signal into the ground and measure the subsequent response, magnetometers detect local, near-surface variations in the strength of the earth's magnetic field related to natural and cultural phenomena. A gradiometer, one type of magnetometer, measures the difference between two sensors separated by a fixed distance rather than the magnitude of the magnetic field, which has a strength of about 53,600 nT (nanotesla, a measure of magnetic field strength) in the project location (National Centers for Environmental Information, National Oceanic and Atmospheric Administration 2018). Broad geological sources of magnetism and the earth's magnetic field affect both sensors equally. Archeological features, on the other hand, generally exhibit much weaker magnetism varying between about ±5 nT and are detected primarily by the lower sensor. Differencing both sensors' measurements effectively eliminates temporal variability (e.g., diurnal variation, but also other periodic and aperiodic magnetic "noise") and broad changes in the magnetic field. However, spatial variation related to smaller archeological and geological features as well as iron or steel items remains.

Magnetometers measure induced and all types of remanent magnetism, although the forms cannot be differentiated by the instrument (Aspinall et al. 2009:11-17, 21-26; Kvamme 2006b:207-208). Magnetism may be induced in materials due to their susceptibility, or tendency to become temporarily magnetized in the presence of a magnetic field, including the earth's field. Susceptibility varies as a consequence of the concentration of naturally occurring magnetizable minerals like iron oxides in soils and rocks. Several natural and cultural factors, often in concert, enhance topsoil susceptibility by concentrating these minerals or converting weakly magnetic iron oxides to more magnetic types (Aspinall et al. 2009:11-17, 21-26; Kvamme 2006b:214-221). For instance, magnetite, one of the more magnetic iron oxides, is created during soil development, and naturally occurring magnetotactic bacteria synthesize the same mineral. Additionally, maghemite, a highly magnetic iron mineral is created through a process—the Le Borgne effect—of reduction and reoxidation when soil with hematite is exposed to low-temperature firing (about 200ºC), either natural or human-caused. Furthermore, bacterial growth and decomposition of organic waste introduced by humans further contributes to topsoil and feature susceptibility. Other human-made or imported magnetic materials, like pottery and fire-cracked rock, are also dispersed across occupations and increase susceptibility. Subsequent human activities that accumulate or remove magnetically enhanced soil (e.g., backfilling a storage pit feature or removing topsoil during the construction of a structure) are sources of susceptibility contrasts—both positive and negative—that can theoretically be detected.

Even in the absence of a magnetic field, some materials exhibit remanence, or residual magnetism (Apsinall et al. 2009:11-17, 21-26; Kvamme 2006b:207-208). Several types of remanence exist, but thermoremanence, which occurs when materials are intensely heated, is most important to archeological contexts. Fired features (e.g., hearths, earth ovens, burned structures) acquire thermoremanent magnetism due to the presence of iron oxides. The magnetic domains of these minerals are randomly oriented in soil, which means they are only weakly magnetic. However, when the minerals are heated beyond their Curie temperatures (about 600ºC) and then cooled, their domains are reoriented and remain aligned with the earth's magnetic field. The consistent orientation of the domains is the source of a feature's strong, residual magnetism. Igneous rocks exhibit thermoremanent magnetism as well, a fact that can complicate feature interpretations (Aspinall et al. 2009:174-175; Kvamme 2006b:207-208).

Magnetic surveys at sites in adjacent regions (e.g., Burks 2014; Kvamme and Ahler 2007; McKinnon et al. 2016) were successful in terms of identifying the types of features that would be expected at Gast Farm. Excavations at Gast Farm and other Woodland sites (e.g., see Freeman 1969; Neverett and Whelan 1996; Smith 1992:201-248) indicate fired features like hearths and earth ovens; basin-shaped refuse and food-processing pits as well as deeper storage pits; and postholes are common features. Due to the relatively small diameter of most posts as well as the spatial resolution of the survey, distinct posts are unlikely to be resolved in a magnetic survey, however. On the other hand, basin-shaped and deeper, undercut pits filled with midden generally exhibit positive magnetic signatures with circular forms. Anomalies associated with fired features are usually similar in shape and diameter, although their maximum measurements may be higher on average (Bales and Kvamme 2005; Markussen 2005). Depending on the depth of the plow zone, house basins may be identifiable as well. Even in environments that have been subjected to plowing for many decades, evidence of mounds and earthworks are visible (Burks 2014; McKinnon et al. 2016).

Two Bartington Grad601-2 instruments, fluxgate magnetic gradiometers with their sensors vertically separated by 1 m, were used simultaneously during the survey at Gast Farm (Figure 7). The Grad601-2 is capable of measuring magnetism with a resolution of 0.1 nT (Bartington Instruments 2016). Furthermore, it can detect objects or features to a depth of about 1.5 m depending on several factors, including their size, density, and contrast with the surrounding soil matrix.

Data Processing

After the survey was completed, several processing steps, described in greater detail by Kvamme (2006c), were followed to correct the raw magnetic data for operator and instrument errors and to enhance visibility of anomalies of potential significance. First, a composite grid was generated from the individual 20-m-x-20-m grid units. Isolated extreme measurements, often caused by the presence of metal in magnetic datasets, were removed or decreased in magnitude with a *despike* function. The data exhibited two additional noise types because transects were surveyed in an alternating or zigzag pattern. One is a striping defect that results when the instrument is incorrectly oriented along a survey transect. The second is a "zipper" pattern defect caused by the instrument operator's mistimed pace in opposite survey directions. These errors were corrected with a *zero mean traverse* algorithm and a *destaggering* function whenever necessary.

Additional steps were taken to enhance image quality of the processed data. An *interpolation* function was used to produce uniform sampling densities (i.e., sampling densities of 0.125 m x 0.5 m were interpolated to 0.25 m x 0.25 m). This step serves two purposes: averaging measurements reduces noise, and increasing the pixel density decreases the pixelated appearance of the image, creating a more continuous and visually appealing result. Finally, a *low-pass filter* was applied to the data to further reduce image noise. Due to the height of the corn stubble at Gast Farm, the instruments were frequently jarred by contact with the vegetation, an issue that creates spurious values. Filtering reduces the effect of such noise. Each procedure was carried out with TerraSurveyor, software designed for processing near-surface geophysical data.

Data Integration and Interpretation

The fully processed magnetic dataset was georeferenced to coordinates (NAD 1983 UTM Zone 15N) yielded by GNSS in Esri ArcGIS 10.5. Prior to this process, however, the GNSS observations were differentially corrected using the Continuously Operating Reference Stations network with locations in Donnellson, Davenport, and Washington, Iowa, which resulted in a computed coordinate accuracy of 5–15 cm (100 percent). Registering the raster image in a Geographic Information System (GIS) facilitated visual comparisons of the magnetic results with aerial imagery and elevation data acquired via the U.S. Geological Survey (https://earthexplorer.usgs.gov/) and Iowa Geographic Map Server (http://ortho.gis.iastate.edu/). Much like other near-surface geophysical techniques, these remote sensing datasets provide complementary information that aids interpretation of the magnetic results. Anomaly interpretation relies on pattern recognition and familiarity with the suite of features one may encounter as well as awareness of magnetic theory and consideration of the magnetic properties of features (Kvamme 2008). GIS methods discussed further below were used to identify and differentiate particular anomaly types that are often indicative of archeological features and to better understand the distribution of potential features across the site. Interpretive maps of Gast Farm were generated by creating vector shapefiles, which illustrate natural and cultural features in the area of the magnetic survey.

RESULTS

The magnetic findings at Gast Farm indicate hundreds of anomalies of likely archeological significance such as midden-filled pits and fired features like hearths and earth ovens (Figure 8). Importantly, the results clarify understanding of the layouts of the Middle and Late Woodland settlements, particularly their roughly circular forms and the presence of central plazas at both locations. Also, while the landowner was said to have leveled a single large mound during the 1950s, the magnetic data clearly show several more clustered near the center of the site.

Erosional Channels

Among the many magnetic anomalies are several types that represent features, objects, or activities unrelated to the period of consideration. Still, these anomalies are important due to their conspicuous patterning. For instance, a grassy drainageway is the source of curvilinear magnetic anomalies toward the southwest corner of the field (Figures 4 and 8). Numerous other positive and negative anomalies, some with lengths approaching 100 m, are distinct due to their dendritic appearance (Figure 9). Comparison of the magnetic data with a recent aerial photograph from 2011 clearly demonstrates a relationship between these anomalies and erosional channels. The aerial photograph shows that in some areas, erosion has removed the vegetation completely while in other locations, the vegetation has been disturbed to such an extent to cause obvious color differences. Where these channels have been backfilled with eroded topsoil, they are indicated by positive anomalies. Negative anomalies, on the other hand, signify locations where topsoil thickness has been reduced and remains in that state. Despite a five-year interval between the acquisition dates of the aerial photograph and magnetic data, the long-lasting effects of erosion are evident in the magnetic results.

Plow Marks

Although their magnetic signature is subtle relative to that of the erosional channels, remnant plow marks extend ENE–WSW across the cultivated field (Figure 10). The linear anomalies are primarily positive, with differences of about 0.5–1 nT from adjacent soils, and regularly spaced 9-10 m apart. Aerial photographs from as early as the 1930s show the field is plowed and tilled in an east–west or north–south direction. The remnant plow marks are diagonal to the typical pattern and perpendicular to the prevailing winds, perhaps indicating an instance of chisel plowing (William Green, personal communication). The magnetic signature results from topsoil settling deeper in the furrows.

Dipolar Magnetic Anomalies

Even more common than anomalies related to erosional channels and plow marks are discrete “point” anomalies, which include positive, negative, and dipolar forms, that range from weakly to highly magnetic. Dipolar anomalies are a common form, with paired, high-magnitude positive and negative measurements (Figures 8 and 11). Two types are apparent, including anomalies with closely-spaced, adjacent poles and others in which the negative pole forms a halo around the positive pole. Both are characteristic of near-surface ferrous (i.e., iron or steel) objects. Examples of the latter likely indicate vertically oriented iron rods such as rebar. Dipolar anomalies are widespread across the field, a pattern that is consistent with its use for agriculture in recent decades. Many of the dipolar anomalies probably represent metal debris from farm equipment. While dipolar and other robust magnetic anomalies related to metal are widespread, the most robust anomalies occur near the farm residence and outbuildings (Figures 8 and 12). These anomalies are caused by large-diameter steel posts along the fence that separates the field and yard. Previous archeological investigations of the site may be another source of metal debris and associated dipolar anomalies.

Combined, magnetic anomalies related to the erosional channels, plow marks, and ferrous metal obscure those that represent fired features, pits, and other archeologically significant features (Figure 8). These anomalies are generally positive, ranging up to about 20 nT, and circular with approximately 0.5–3 m diameters (Figure 13). While these relatively weaker anomalies appear “monopolar” as opposed to those previously described, they too are dipolar in form. However, due to the earth’s magnetic field inclination, which is nearly vertical at our latitude, their negative poles are located farther from the gradiometer and often go undetected.

Magnetic Anomaly Identification

Anomalies are generally identified directly based on visual inspection, although this process is tedious and time consuming, leading some (e.g., Kvamme 2013) to argue for the adoption of automated approaches to feature recognition. An approach that differentiates magnetic anomaly types with the aid of certain GIS techniques maintains the flexibility of a standard visual inspection but adds a level of objectivity and semi-automation.

Dipolar Anomalies

To isolate dipolar and other robust anomalies related to ferrous metal, two threshold layers showing positive magnetism above 2.5 nT and negative magnetism below -2.5 nT were created by reclassifying the magnetic dataset (Figure 14). A narrower range would be ideal due to some dipolar anomalies with magnetic poles that measure closer to the mean ($\bar{x}$ = -0.04). However, nearly 98 percent of the measurements are within the ±2.5 nT range, so threshold values closer to zero would include significantly more anomalies, many of which are not of clear archeological significance, and render the approach useless. After the threshold maps were created, a 0.25 m buffer was applied to both so that the adjacent positive and negative poles of each dipolar anomaly would overlap. A Boolean AND operator was used to quickly detect their overlap in the GIS. Obvious dipolar anomalies with weakly magnetic negative poles were identified by reviewing the magnetic data visually since they would not be discovered by threshold mapping. On the other hand, a small number of dipolar anomalies that likely indicate fired features (e.g., hearths or earth ovens), which often exhibit a circular positive pole about 0.5–3 m in diameter, a smaller negative pole on the north side, and measurements approaching 20 nT, were removed from the threshold maps. Non-overlapping positive and negative anomalies were finally removed, leaving only dipolar and robust magnetic anomalies related to metal (Figures 12 and 14).

Positive Anomalies

While the process of finding dipolar anomalies is relatively straightforward, identifying positive anomalies of likely archeological relevance is more difficult. The sources of positive anomalies are many, including various types of archeological features as well as non-archeological factors. Rodent burrows, magnetic rocks, mounded topsoil, and instrument noise, among other sources, create anomalies that appear much the same as those caused by archeological features. Applying a low-pass filter to the magnetic dataset, a step discussed previously, largely accounts for subtle instrument-related anomalies (e.g., spurious values created when the instrument makes contact with the corn stubble). GIS techniques further facilitate the identification of positive anomalies, most of which ideally relate to the Middle and Late Woodland occupations at Gast Farm.

One procedure for better visualizing these anomalies is to replace all dipolar and robust magnetic anomalies with the data mean. To do so, the overlapping positive and negative anomalies previously identified with threshold mapping were merged, and a reclassify function was used to convert their extreme values with the average of the magnetic dataset ($\bar{x}$ = -0.04). A cell by cell comparison of that raster and the complete magnetic dataset was then performed with a logical OVER operator. The output of the operation consists of a raster similar to the initial magnetic dataset, although values in locations of dipolar and robust anomalies have been replaced with the mean (Figure 15). The procedure essentially subtracts one type of magnetic anomaly from the dataset, yielding a clearer view of more significant anomalies.

Plow marks are another source of noise that may be addressed using image processing algorithms (Figure 10). Since the plow marks are regularly oriented and spaced across much of the cultivated field, a fast Fourier transform is potentially capable of isolating and removing the frequency associated with them. In this particular case, the plow marks are too subtle to be identified in the complete dataset. However, visualization of important anomalies associated with the Woodland components is improved when the processing step is limited to smaller areas where the marks are especially prominent (Figure 16).

Erosional channels within the cultivated field also contribute to the magnetic results due to topsoil disturbance. The dendritic patterning described above is most apparent, although discrete positive anomalies likely associated with deposited topsoil are common along the course of each channel (Figures 9 and 17). These positive anomalies look no different from others related to archeological features, but due to their location, interpreting them with certainty is problematic. For this reason, a relatively small number of positive anomalies located wholly within obvious erosional channels, identified based on the magnetic results and aerial photographs, were excluded from further interpretation and analysis.

Finally, a second threshold map of positive magnetism above 2.5 nT was generated using a reclassify function, although in this instance, dipolar anomalies and anomalies in erosional channels were omitted. Archeological features are undoubtedly associated with anomalies lower in magnitude, but differentiating them from the background magnetic noise is difficult. To account for some anomalies caused by non-archeological sources, which are likely smaller in area on average than those related to features, those less than 0.25 m^2 in area were excluded as well. Following these steps, a total of 452 potential pits, hearths, earth ovens, and other archeological features remain (Figure 18).

Village Plans

Two distinct clusters of positive magnetic anomalies correspond with the Middle and Late Woodland settlement plans as previously inferred from artifact distributions and soil marks. An analysis of surface-recovered ceramics associated with the Middle Woodland Havana-Hopewell community indicated an oval-shaped concentration near the east side of the cultivated field (Green et al. 2016; Figure 2). A dense concentration of anomalies overlaps with this cluster of sherds and extends farther to the northeast. More importantly, the distribution of likely features exhibits patterning that is telling of the village's layout. "Ring midden" settlements are well known for Late Woodland Weaver phase and contemporaneous sites (Esarey et al. 1984; Freeman 1969; Green 1992), but the concentration of positive magnetic anomalies at the earlier Middle Woodland habitation at Gast Farm is indicative of a similar village plan. In contrast, Middle Woodland communities often consist of a few large, extended family dwellings built without any particular arrangement (Braun 1991:369-373; Smith 1992:240). The oval-shaped ring of anomalies has dimensions of about 170 m x 120 m, with its long axis oriented NE–SW (Figures 18 and 19). A likely plaza, an area with relatively fewer magnetic anomalies, lies at its center and has approximate dimensions of 60 m x 40 m.

The plan of the Late Woodland settlement, located a short distance to the west, is known not only from the clustering of Weaver sherds but also from an obvious ring of dark soil related to midden deposits. This ring is evident in aerial photographs of the site (Green et al. 2016; Figures 2 and 20). In fact, the concentration of positive magnetic anomalies in this area closely parallels the darker soils. However, it is clear from the distribution of probable features that the community extended beyond the survey area, which is bordered to the west by a modern gravel road and the farm residence. Moreover, alluvial fan deposition has perhaps obscured portions of the settlement given the relative weakness of the magnetic anomalies in this location compared to those visible in the Middle Woodland occupation. Anomalies along the margins of the village, particularly the northern and eastern edges, are muted. Based on the distribution of anomalies greater than 2.5 nT in magnitude, the community appears to have a similar oval-shaped plan with dimensions of about 150 m x 110 m, although weaker anomalies extend nearly 40 m to the east (Figures 18-20). Additionally, a probable plaza about 50 m x 30 m in area with few anomalies and light-colored soil is situated near the center of the settlement.

The threshold maps of positive magnetic anomalies appear to indicate clustering of likely features within both communities (Figures 18 and 20), but visualizations such as these can be misleading and do not indicate any statistical significance related to the spatial distribution of anomalies. Following previous investigations of the site (Green et al. 2016), hot spot statistics like Getis-Ord Gi* may be used to identify areas of concentrated and dispersed points. The Getis-Ord Gi* test requires point data with attribute values rather than simple spatial locations, but the statistic is useful if the points are first aggregated so that "counts" within a given area serve as an attribute. In this instance, 10-m fishnet polygons, which are meant to replicate the ceramic sherd surface collection strategy, were created within the geophysical survey area. The Getis-Ord Gi* statistic was applied to these aggregated values, and the resulting z-values were interpolated and smoothed, yielding a visualization of statistically significant clusters of anomalies indicating archeological features (Figure 21).

The statistical test also indicates an oval-shaped distribution of positive anomalies associated with the Middle Woodland Havana-Hopewell settlement (Figure 21). However, two particularly dense clusters of probable features are located on the east and west sides of the plaza, a pattern that roughly parallels previous findings concerning ceramic sherd distribution (Green et al. 2016). Likewise, the densest cluster of positive anomalies within the Late Woodland community generally matches the distribution of Weaver ceramics. Specifically, anomalies are concentrated along the southwest margin of what appears to be a plaza.

Fired Features and Pits

These positive magnetic anomalies point to various types of archeological features, among the most common of which are refuse, food-processing, and storage pits. Hearths and earth ovens form thermoremanent anomalies while pits generally cause induced anomalies, but magnetic gradiometers do not differentiate remanent and induced forms of magnetism. Still, previous investigations of hearths and pits have indicated bimodality in their magnetic readings, with hearths exhibiting higher average maxima (Bales and Kvamme 2005; Markussen 2005). However, the distribution of positive magnetic anomalies at Gast Farm is unimodal and skewed right (Figure 22). Anomalies with diameters of 1.5–3 m and large magnitudes such as those greater than 7.5 nT are indicative of fired features, but determining the source of more anomalies with greater certainty will require a program of testing.

Houses and Related Architectural Features

Likewise, undeniable magnetic evidence of architectural features such as houses within either Woodland community is lacking at the site. The mean floor area of excavated Middle Woodland houses is just under 70 m^2 while Late Woodland dwellings are less than half that size (Braun

1987, 1991; Freeman 1969; McConaughy 1993; Smith 1992:201-248; Wray and MacNeish 1961). Houses from both periods are typically circular or subrectangular in form, with numerous features located within and outside the structures.

The absence of clear house perimeters at Gast Farm may be a consequence of the regular cultivation activities that occurred at the site for many decades. In particular, deep plowing perhaps truncated or destroyed the upper portions of archeological features, including house floors. Moreover, dwellings at the Rench site were built with wattle and daub construction (McConaughy 1993), and recovered daub suggests the same technique was used at Gast Farm (Whelan et al. 1992). Unless burned, such materials would likely produce a weakly magnetic signature, one that would be difficult to distinguish from the general background noise.

That said, subtle indications of several potential architectural features are noticeable in both the Middle and Late Woodland components of the site (Figure 23). The anomalies that represent them are consistent with previous findings at other Woodland sites, with oval or circular shapes and diameters that range from about 4.5 m to 11.5 m. Each exhibits a ring of weak magnetism, which perhaps indicates the post molds from the structures' exterior walls. Possible intermural features vary. Some structures appear to have a single prominent anomaly near their centers, maybe indicating the location of a hearth. In fact, one such anomaly (Figure 23, center) could represent a feature like the possible sweat lodge at the Weaver type site depicted by Wray and MacNeish (1961:Figure 1). Others have one or more weakly magnetic anomalies that may point to storage, refuse, and food-processing pits. Of course, these preliminary interpretations require testing to confirm the exact sources of the anomalies, but doing so will prove useful for identifying additional houses.

Earthworks and Mounds

Large-area magnetic anomalies related to ceremonial structures at Gast Farm are clearer. Soil marks visible in aerial photographs suggest the presence of a potential geometric earthwork with a nearly 175-m-diameter circular or polygonal outline (Green et al. 2016; Whittaker and Green 2010; Figure 2). The use of imported soils to construct the earthwork would explain the apparent soil color difference, but no evidence of the human-made construction is visible topographically (Figure 3). Moreover, no hint of the earthwork is noticeable in the magnetic data (Figure 8). While cultivation activities would have likely disturbed the supposed earthwork in recent decades, it seems unreasonable to suggest that all traces of a feature of such extent would be removed.

Although one mound was probably leveled by the landowner during the 1950s, concentric rings of positive and negative magnetism indicate the presence of several additional mounds clustered near the center of the cultivated field (Figure 24). Moreover, elements of the mounds' construction and use remain apparent despite many decades of cultivation. The most conspicuous mound is represented by a ring of negative magnetism approximately 13.5 m in diameter (M1). This anomaly is encircled by a more subtle halo of weakly positive magnetism with a diameter of about 17.5 m. A small positive anomaly near the center of the mound perhaps signifies a burial chamber or tomb.

Light-colored soils mark the location of a larger circular mound immediately to the west (M2; Figures 2 and 24). This mound, which is nearly 22 m in total diameter, also exhibits concentric rings of higher and lower magnetism and a possible tomb at its center. Presumably, the alternating pattern of positive and negative magnetism, which is shared by most of the mounds, relates to the use of soils of varying magnetism—perhaps succeeding layers of magnetically enriched, organic topsoil and subsoils—during their construction. Moreover, the signature indicates the mound base, or the bases of these distinct soil layers, and the burial chambers remain intact below the plow zone.

At least two additional mounds are located to the north (Figure 24). The northernmost is circular in plan and approximately 12 m in diameter, with its perimeter marked by a positive anomaly (M3). The mound contains the clearest evidence of a central burial chamber, which is indicated by a positive anomaly nearly 3 m in length and about 1.5 m wide. The mound to its south appears different in form and may represent an elongated or biconical mound structure like that surveyed by McKinnon and colleagues (2016) at the Kamp Mound Group in Illinois (M4). Their Mound 7 ostensibly consists of two sequentially constructed tomb complexes that were capped simultaneously or a primary tomb complex with an intrusive tomb and extended ramp that were later capped. Whether the mound at Gast Farm represents similar construction activities is unclear. The most apparent element of the mound is an approximately 12-m diameter circle, which is perhaps the primary or initial mound construction, represented by a positive magnetic anomaly. A diffuse, weakly magnetic anomaly is located at its center and likely indicates a tomb. The mound also appears to have been elongated nearly 5 m to the east, but no secondary or intrusive tomb is noticeable. While these mounds are the most obvious examples, the group at Gast Farm possibly consists of as many as six or seven mounds.

CONCLUSIONS

A two-week magnetic gradiometry survey was undertaken at Gast Farm (13LA12) in Louisa County, Iowa, in November 2016 by MWAC archeologists Steven De Vore and Adam Wiewel (Figure 1). Although substantial information concerning the site's multiple Woodland components was known due to systematic surface collections and extensive test excavations (Figure 2), our investigation yielded many new insights. Numerous magnetic anomalies with dipolar forms, which generally indicate the presence of ferrous metal objects, are widespread across the 8.64-ha survey area, reflecting its long-term use for cultivation (Figures 8 and 12). Patterning is evident in the distribution of these anomalies. Specifically, a linear pattern of anomalies in the northern part of the field relates to a non-extant fence line that is visible in aerial photographs from the 1930s through the 1950s (Figure 11). Many other weakly magnetic linear anomalies, oriented approximately ENE–WSW and spaced about 9–10 m apart, represent plow marks (Figure 10). Their orientation is unique compared to those visible in aerial photographs from as early as the 1930s. The anomalies like represent an episode of chisel plowing diagonal to the regular cardinal-direction pattern. More recently acquired aerial photographs illustrate the relationship between erosional channels and many curvilinear and dendritic anomalies (Figure 9). Positive anomalies caused by the accumulation of eroded topsoil are of particular importance due to their similarity to those resulting from archeological features.

Magnetic anomalies of likely archeological significance are generally subtler and are obscured by those related to metal, plow marks, and erosional channels (Figure 8). Various GIS and image processing methods were therefore used to enhance the appearance of the most probable features (Figure 15). Over 450 positive magnetic anomalies indicating fired features, such as hearths and earth ovens, as well as various pit types were identified, although they look much alike magnetically (Figures 18 and 20). While gradiometers detect multiple forms of magnetism, including types that are characteristic of different features, they cannot distinguish the forms (Figure 22). Still, the distribution of these apparent features clearly demonstrates the layouts of the two Woodland settlements (Figures 19 and 21). The Late Woodland Weaver phase settlement at Gast Farm has an oval-shaped perimeter with a distinct central plaza evidenced by a relative absence of anomalies. This layout, which is characteristic of contemporaneous Woodland occupations and known as "ring midden," is noticeable due to refuse deposited around dwellings that surround a central plaza. This pattern is recognized among Late Woodland communities, but the Middle Woodland Havana-Hopewell occupation exhibits a similar form, perhaps making it one of the earliest sites with such organization (Smith 1992). Additionally, spatial statistics confirm the clustering of anomalies related to the two occupations and show areas of both villages contain significant concentrations of likely features. While less definitive, some weakly magnetic features may represent the perimeters of architectural features like dwellings, some of which appear to have interior features (Figure 23).

Among the most impressive results at Gast Farm is the finding that the burial and ceremonial complex is substantially different from the prior understanding of its composition, which was based primarily on aerial imagery. The landowner is thought to have leveled a single mound during the 1950s, although soil marks associated with the feature continued to mark its location in more recent aerial photographs. Additionally, aerial photographs and thermal infrared imagery indicated the presence of a much larger earthwork, although neither this feature nor the mound are clearly discernable topographically. Evidence of the possible earthwork is absent from the magnetic data. However, the locations of four remnant mounds, and perhaps several others associated with the Middle Woodland occupation, were discovered during the survey (Figure 24). Each is circular in plan with the exception of one, which is elongated or biconical in form. Moreover, positive magnetic anomalies near the centers of each mound point to the locations of burial chambers or tombs. Despite many decades of cultivation and other impacts, many features associated with the Middle and Late Woodland components at Gast Farm were revealed by the magnetic gradiometry survey. While our results certainly support findings from previous investigations, they also improve our understanding of this complicated site.

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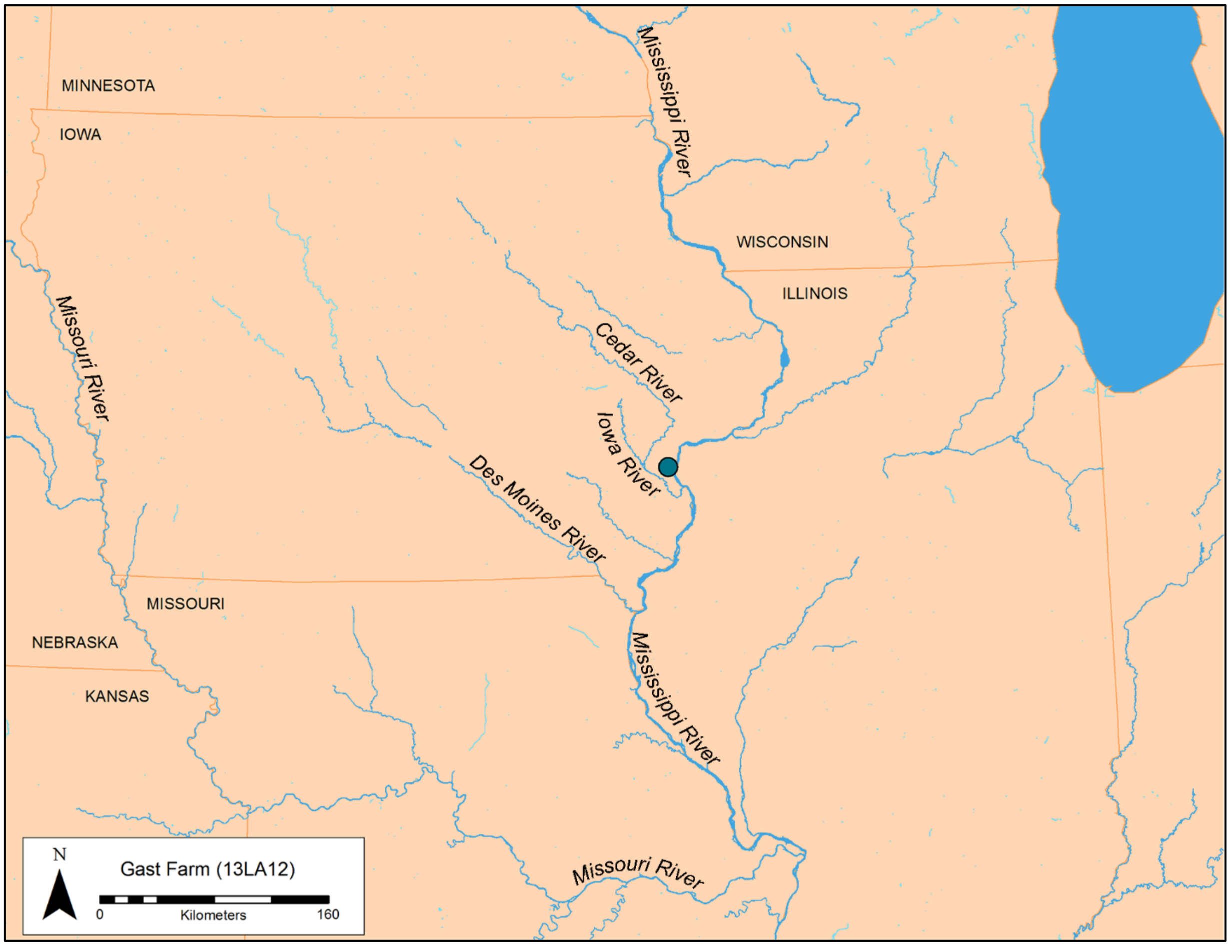

Figure 1. Location of Gast Farm (13LA12) in southeast Iowa represented by a dot near the map's center.

Figure 2. View of Gast Farm in an April 27, 1964 black-and-white aerial photograph (AR1VBAD00010043) with outlines of the Middle and Late Woodland communities inferred from ceramic sherd concentrations and a Hopewell mound and earthworks (Aerial photograph available from the U.S. Geological Survey).

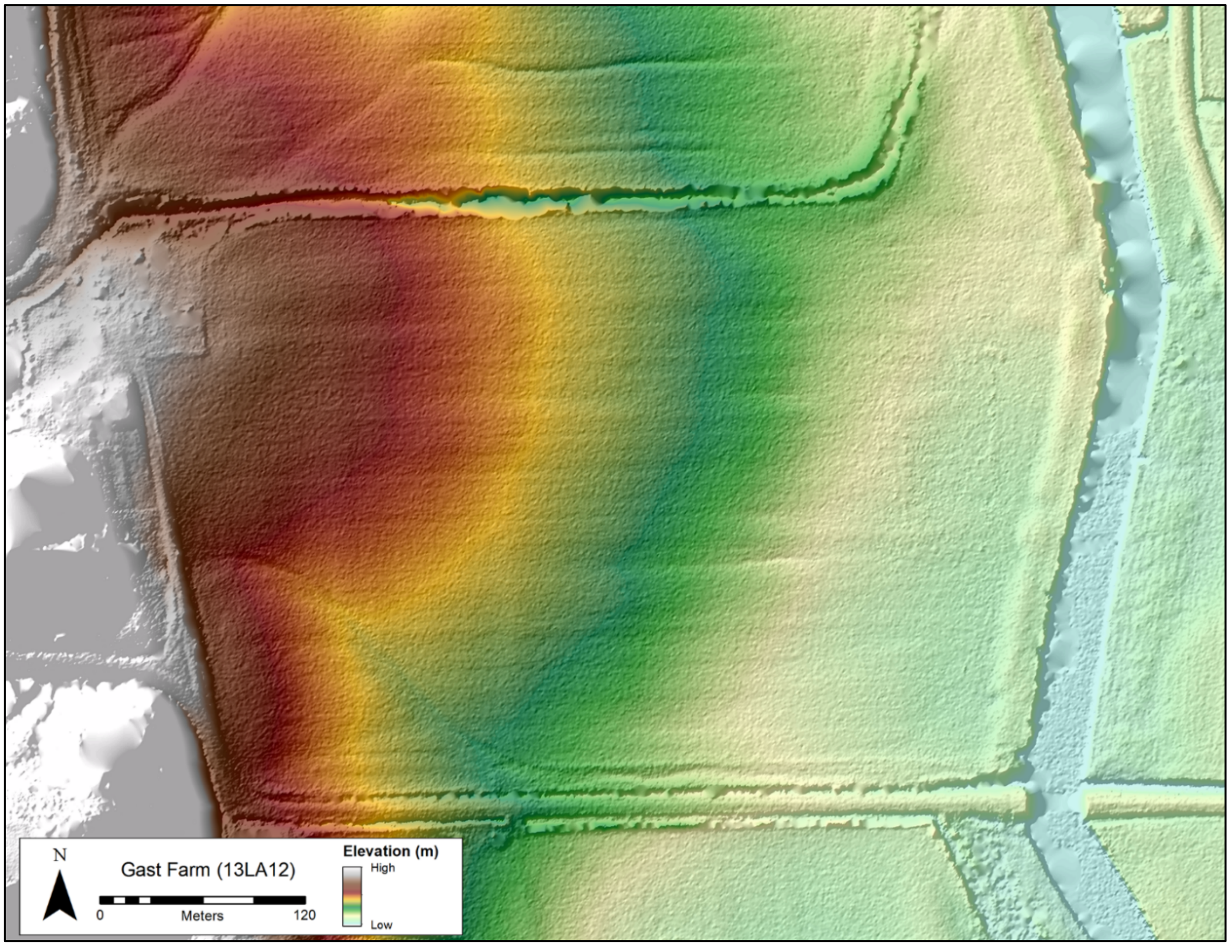

Figure 3. Color shaded relief visualization showing the prominent alluvial fan atop which the Gast Farm site is located. The site extends across most of the cultivated field centered within the figure (Elevation data available from the U.S. Geological Survey).

Figure 4. Geophysical survey area at Gast Farm with 297 complete 20-m-x-20-m grids. The shaded area illustrates the portion of the field in which the survey was completed (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

Figure 5. Positioning a backsight point and determining the survey grid orientation with a Ushikata surveying compass (left) and recording the backsight location with a Trimble 5500+ robotic total station (right) at Gast Farm.

Figure 6. Documenting the locations of survey grid corners with a Trimble Geo 7X and Tornado dual frequency antenna.

Figure 7. Bartington Grad601-2 fluxgate magnetic gradiometer system in use at Gast Farm. Note the survey ropes used to facilitate the survey effort.

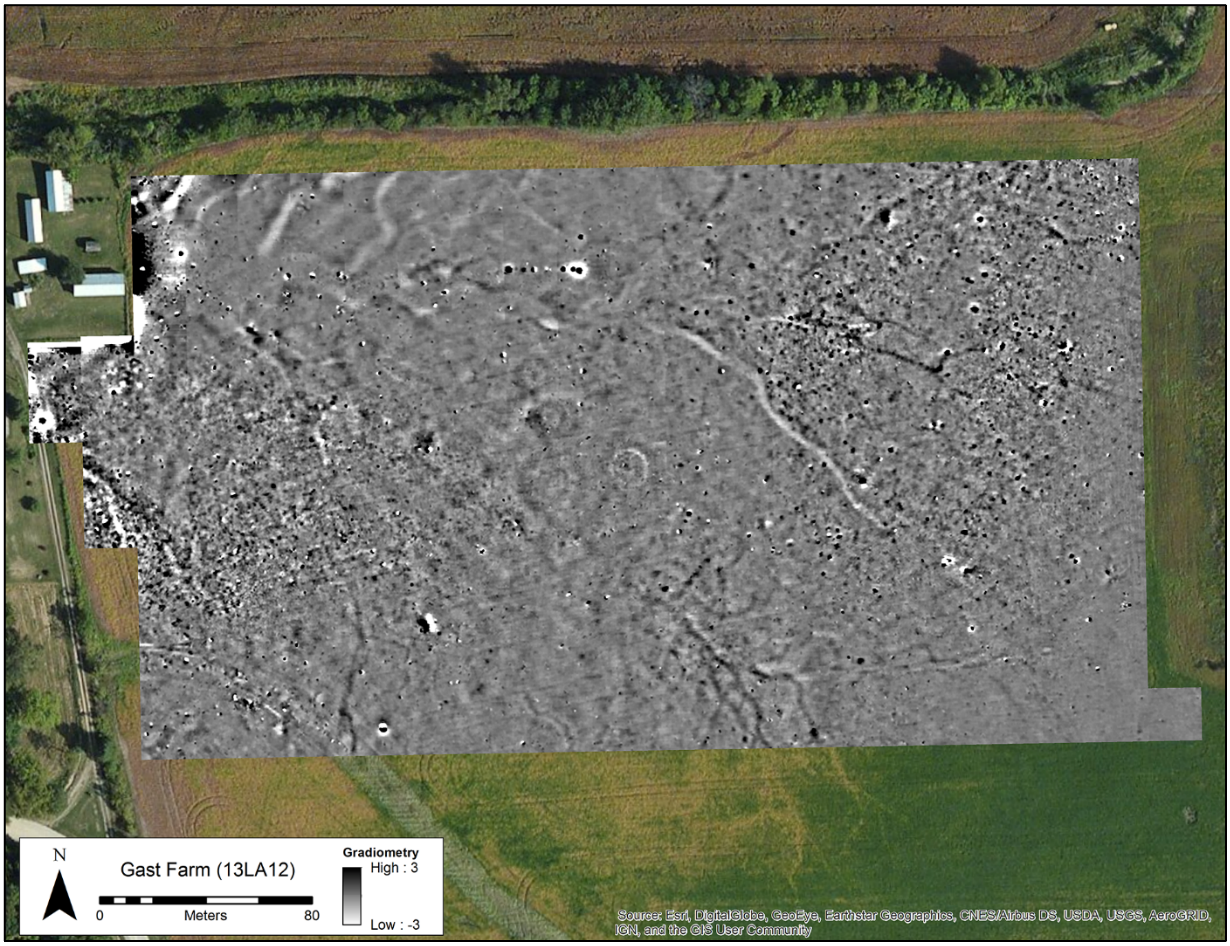

Figure 8. Results of magnetic gradiometry survey at Gast Farm (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

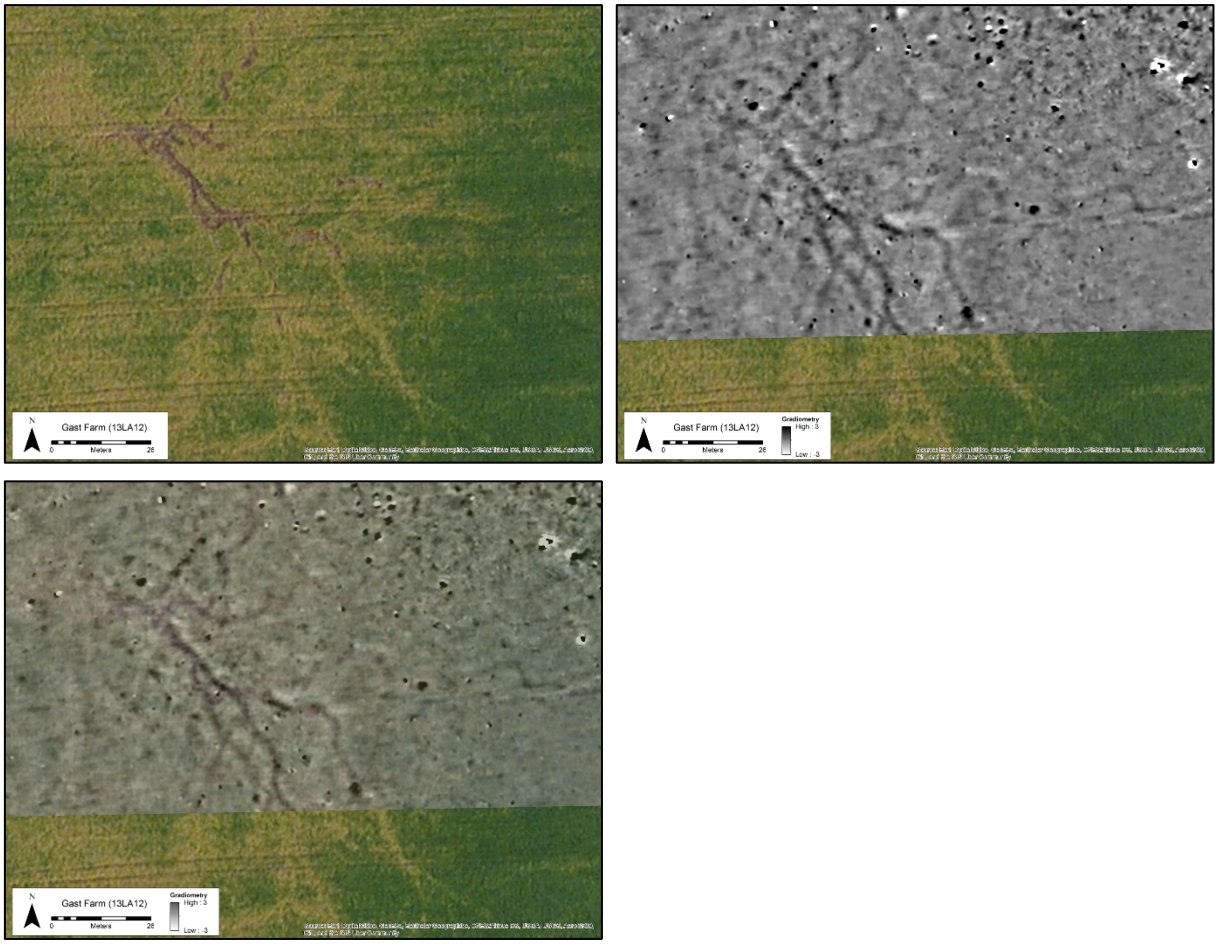

Figure 9. A September 12, 2011 aerial photograph (upper left) in which erosional channels are visible as vegetation and soil marks with clear magnetic signatures (upper right). Their relationship is illustrated when the magnetic data are made semitransparent and overlaid on the aerial photograph (lower left) (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

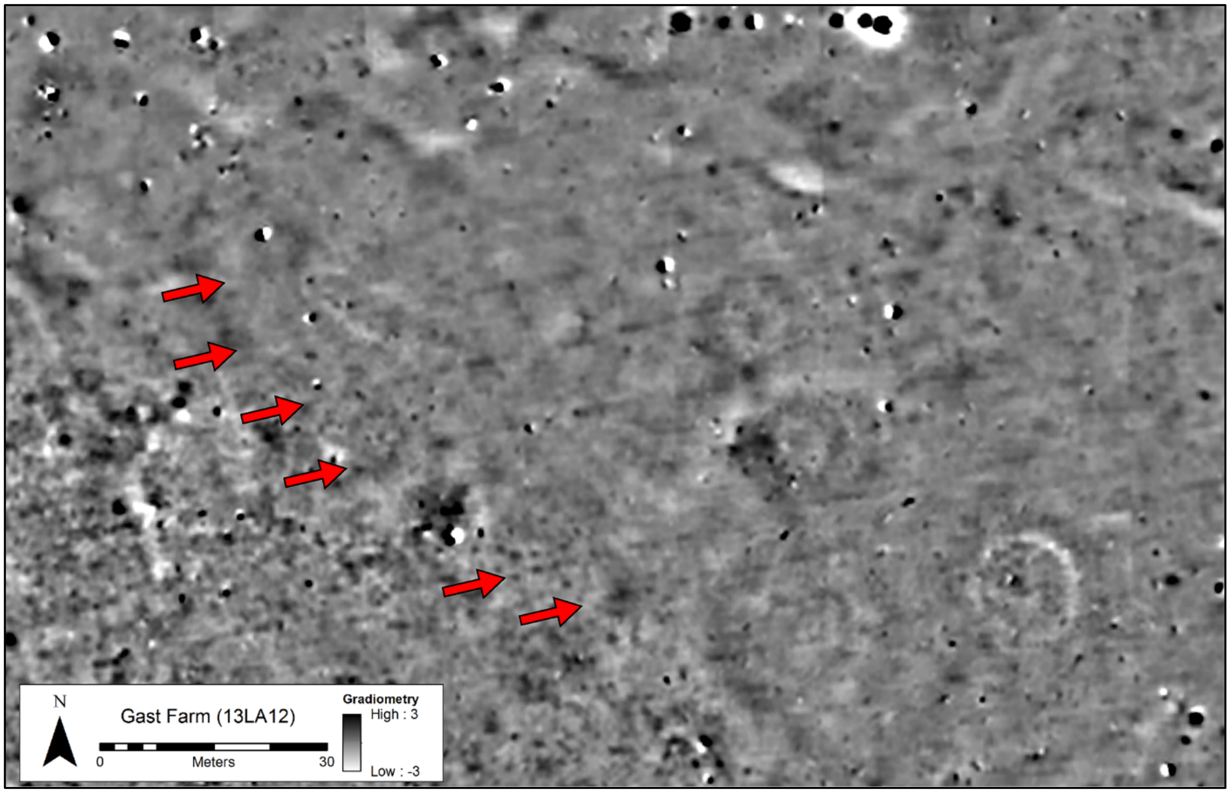

Figure 10. Subtle plow marks (noted with red arrows) visible in the magnetic data.

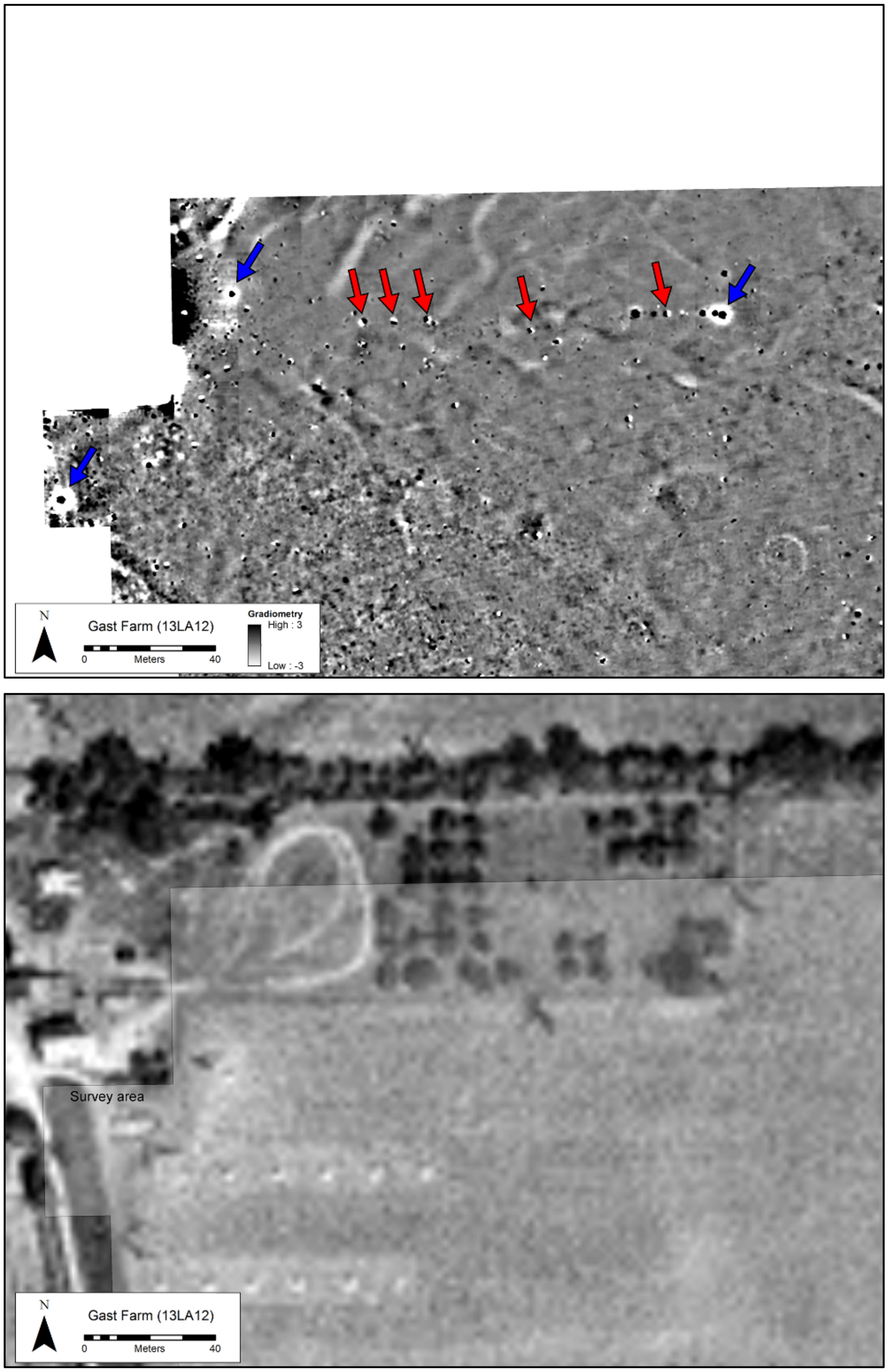

Figure 11. Examples of dipolar anomalies (top), including one type with adjacent positive (black) and negative (white) poles (red arrows) and another in which the negative pole forms a halo around the positive pole (blue arrows). Note the relationship between the dipolar anomalies and a fence, which no longer exists but is apparent in a 1930s aerial photograph (bottom) (Aerial photograph available from the Iowa Geographic Map Server).

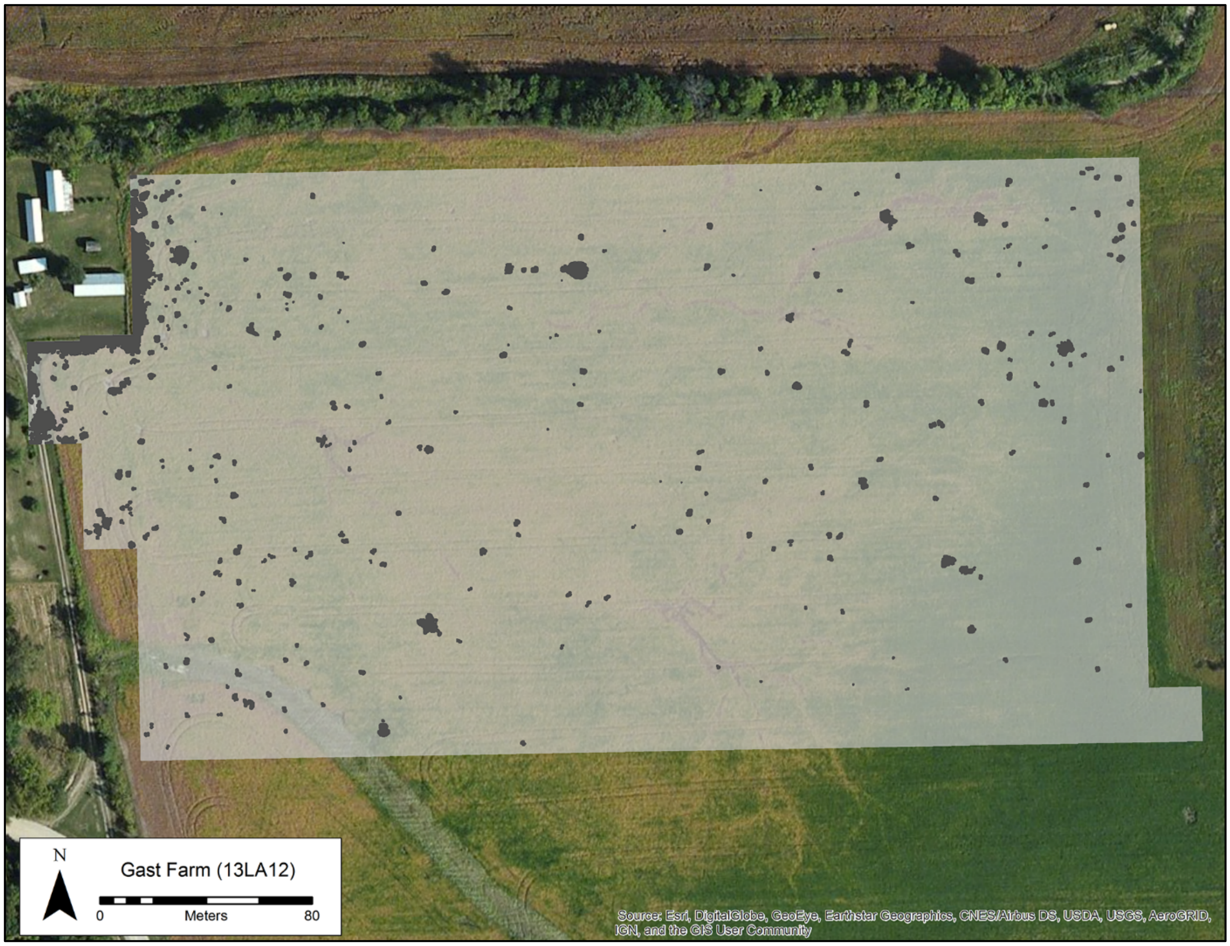

Figure 12. Distribution of dipolar and other robust anomalies related to ferrous metal (marked with gray) at Gast Farm (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

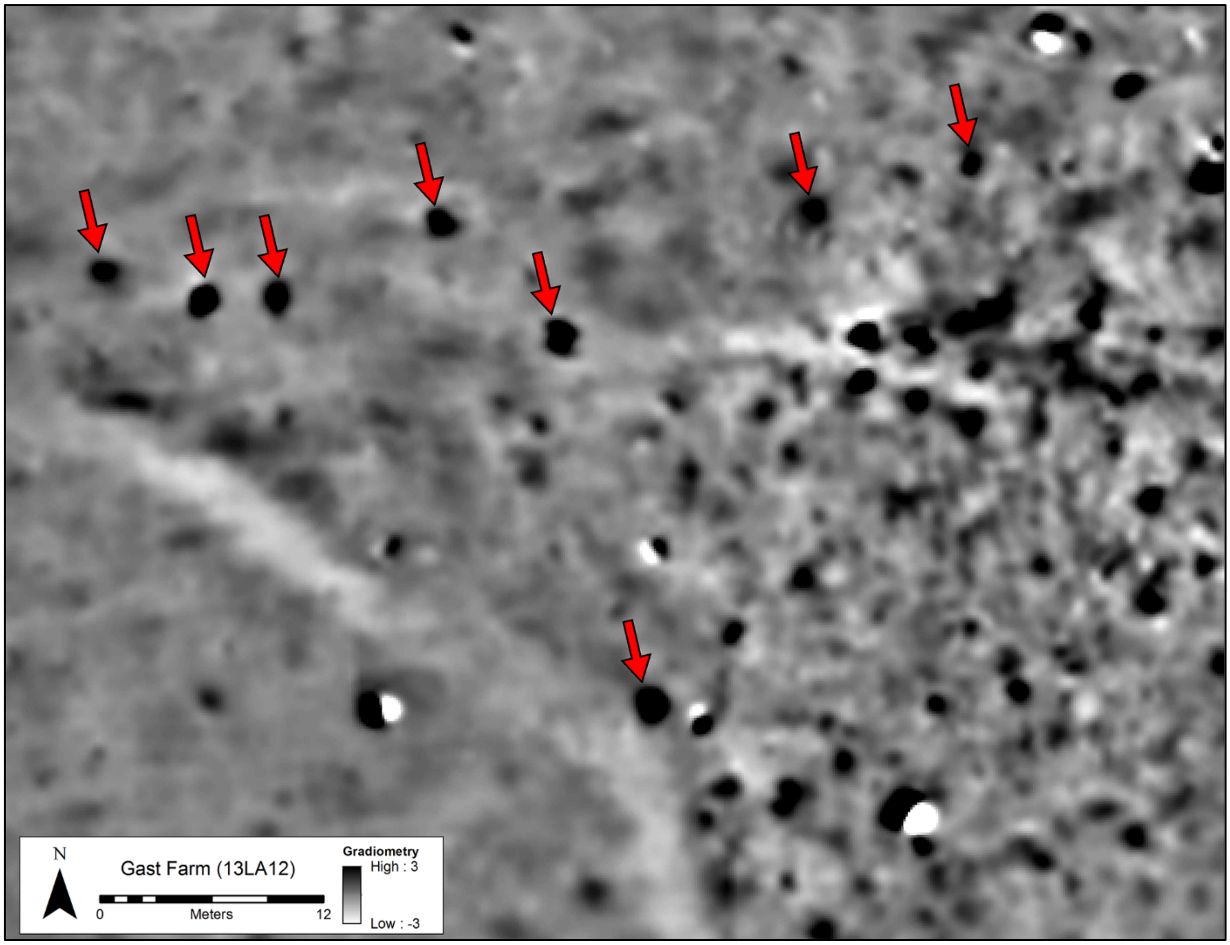

Figure 13. Examples of positive magnetic anomalies (noted with red arrows) that likely represent fired features, pits, and other archeological features.

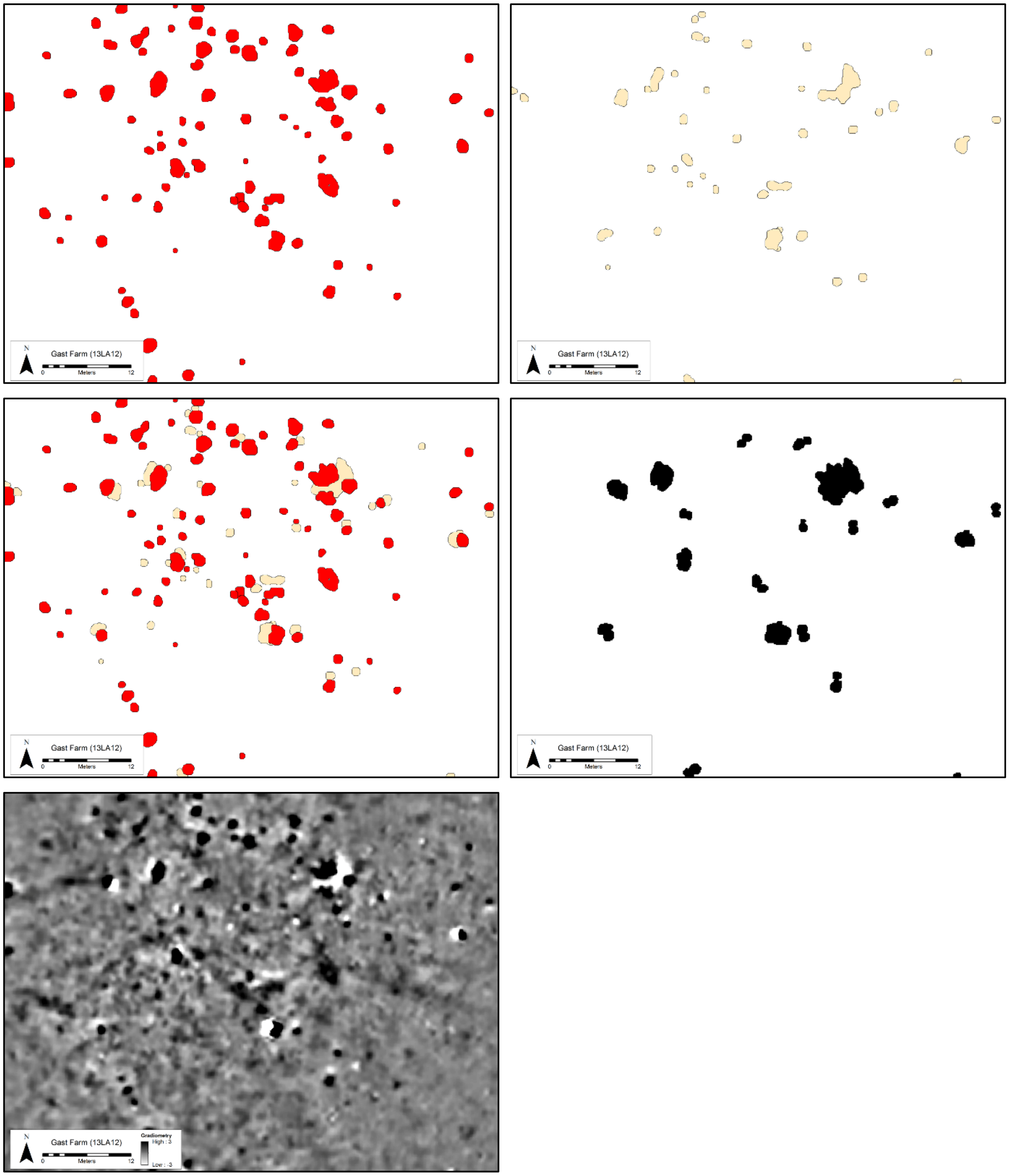

Figure 14. Close-up view of magnetic survey results, showing a threshold map of magnetism greater than 2.5 nT (upper left, labeled red), a threshold map of magnetism less than -2.5 nT (upper right, labeled tan), a combined threshold map of positive and negative magnetism (center left), a threshold map illustrating only dipolar anomalies (center right), and the magnetic dataset (lower left).

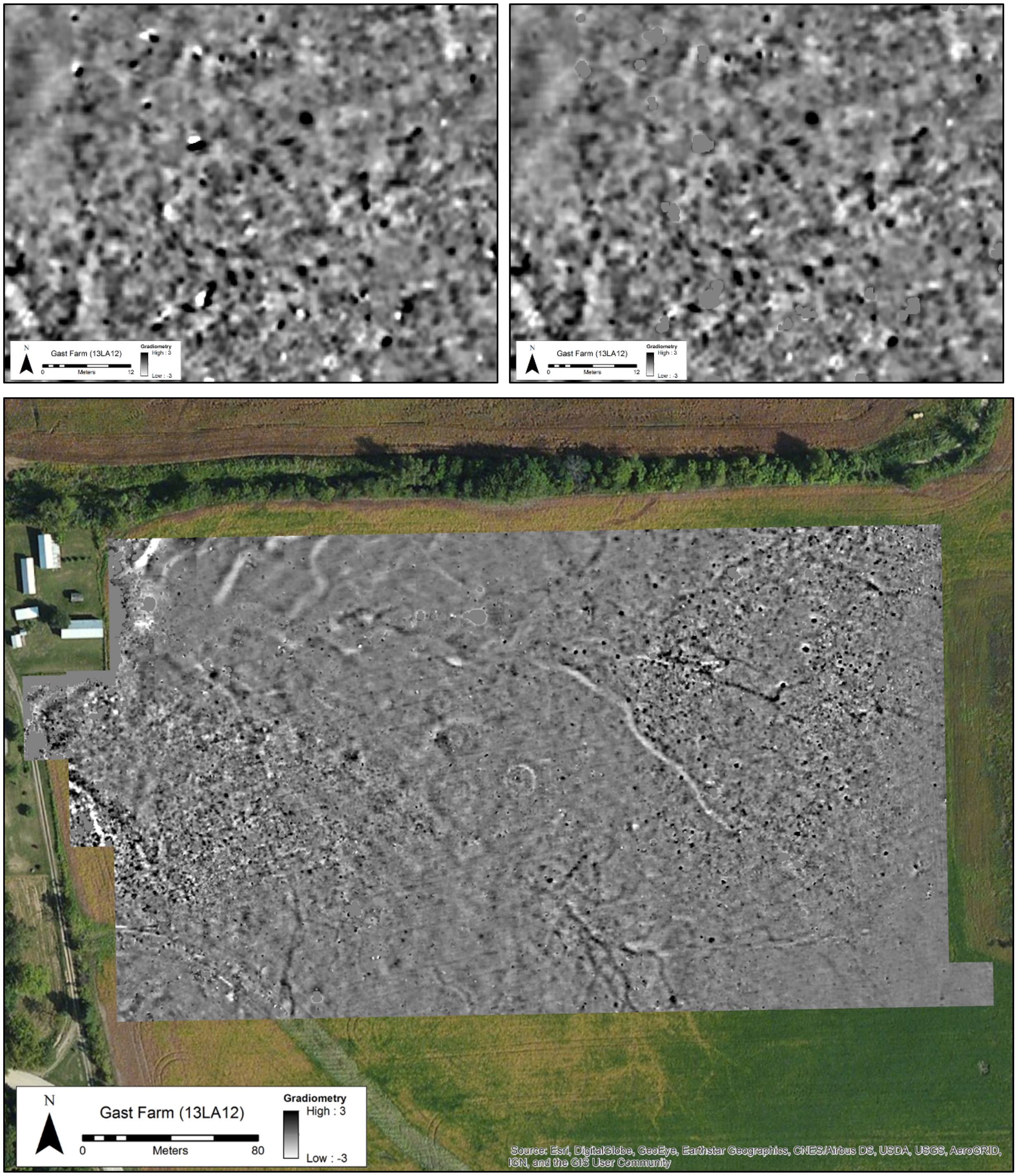

Figure 15. Close-up view of the magnetic survey results (upper left) and the same image after dipolar anomalies have been replaced with the data mean (upper right). The complete magnetic results (bottom) can be compared with Figure 8 to better understand the significance of this procedure (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

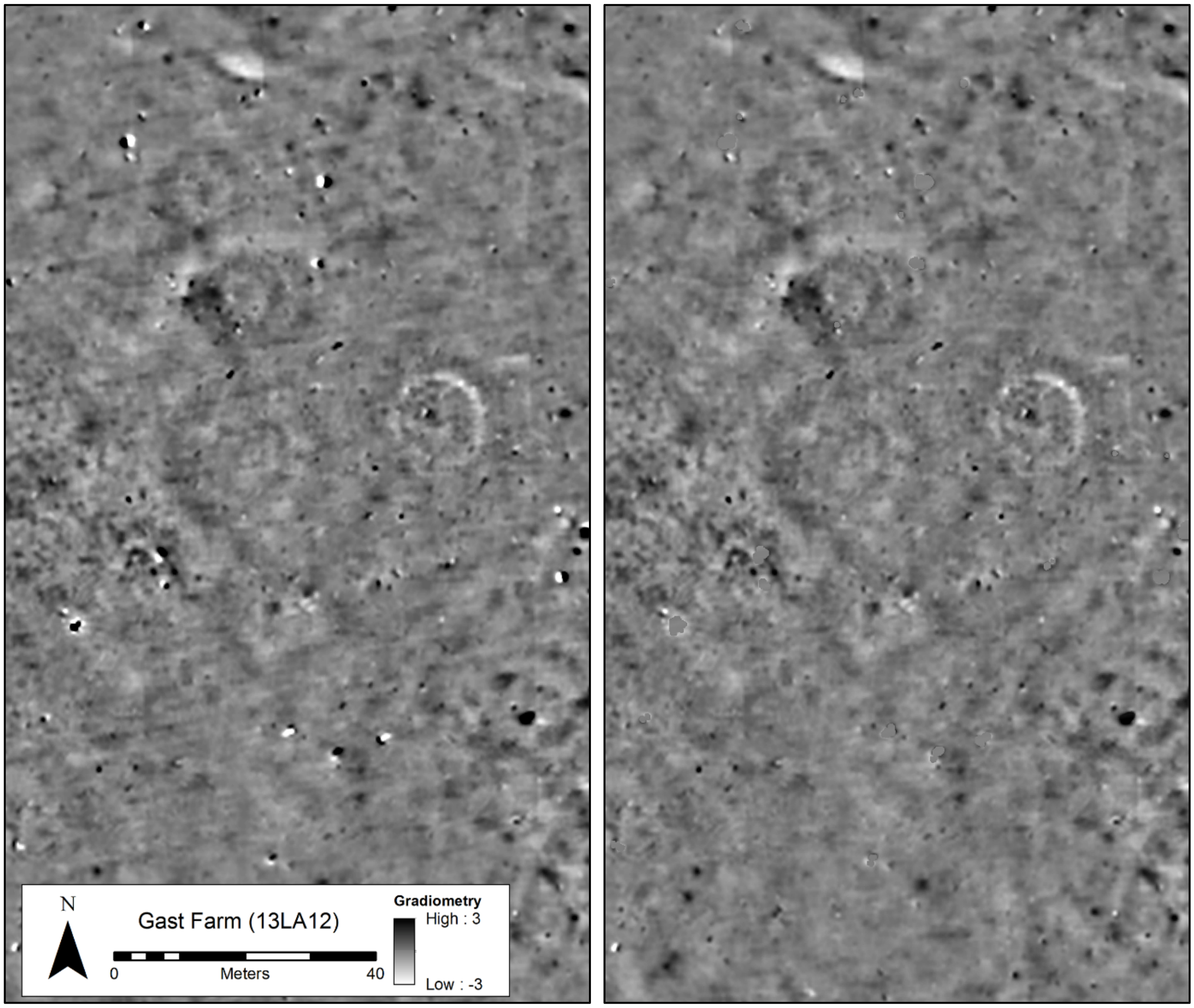

Figure 16. Example of magnetic survey results (left) after dipolar anomalies have been replaced with the data mean and plow marks have been reduced using Fourier methods (right).

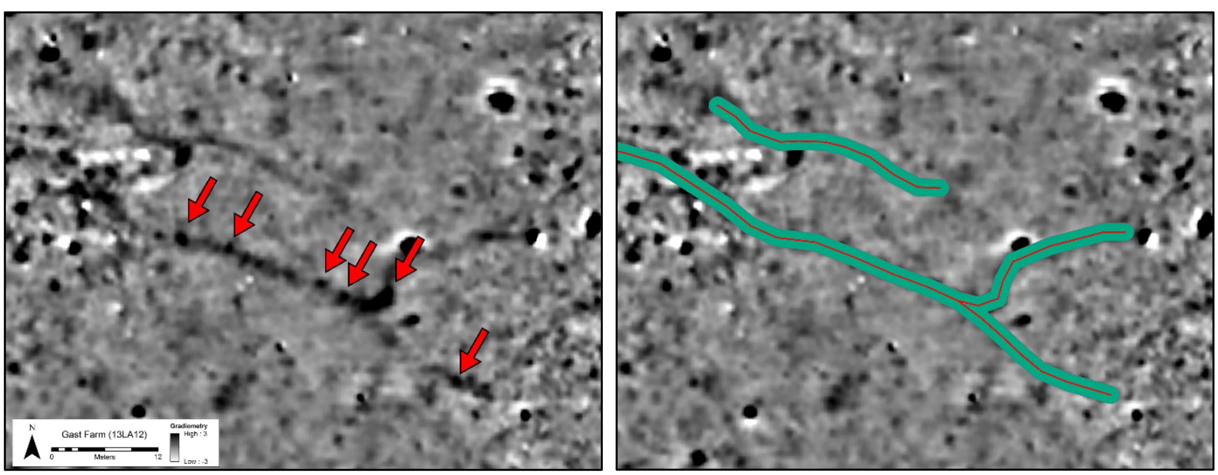

Figure 17. Positive anomalies (left, noted with red arrows) associated with erosional channels (right, marked with green and red lines), which were excluded from the final interpretive map of likely archeological features.

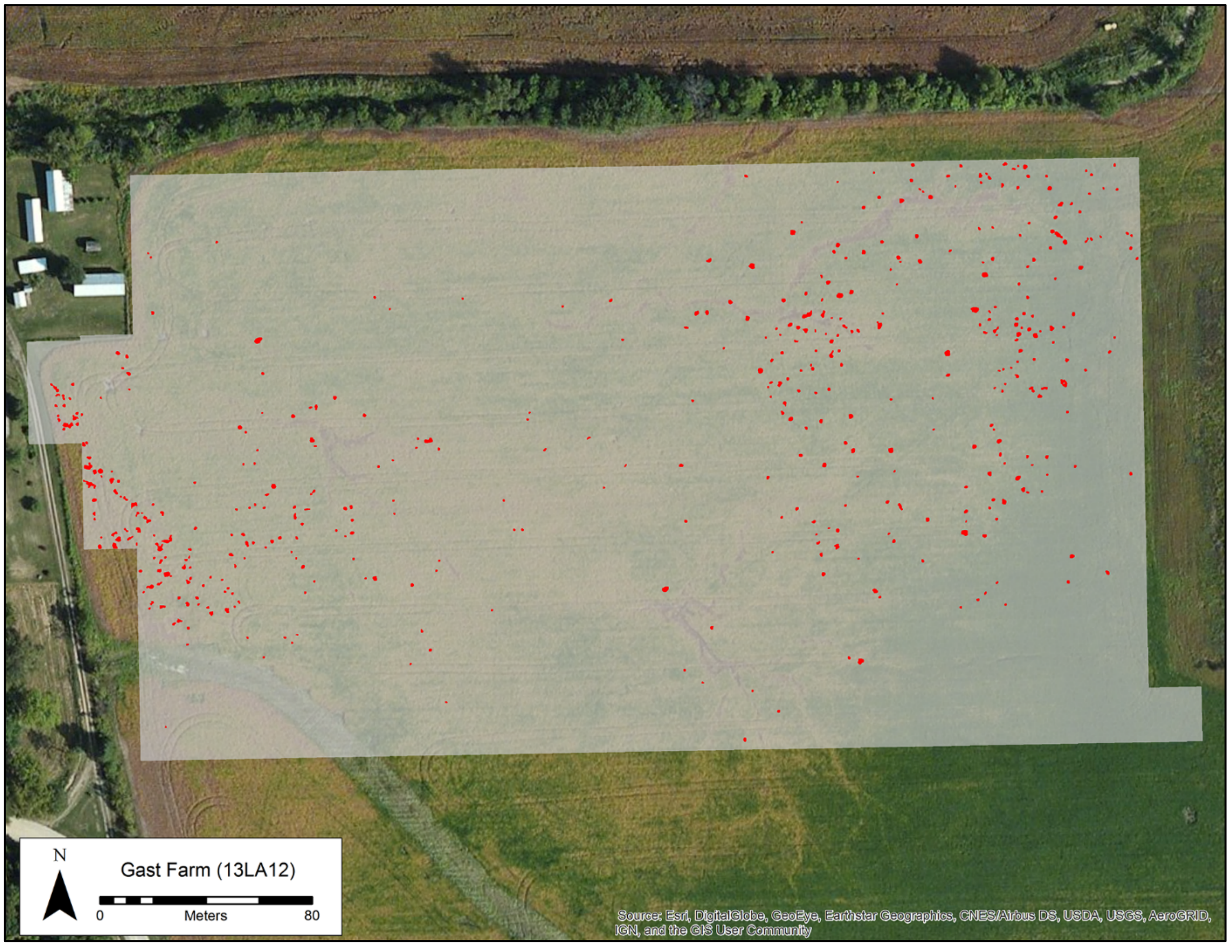

Figure 18. Distribution of positive magnetic anomalies (marked with red) at Gast Farm. Most are likely related to archeological features associated with the two Woodland occupations (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

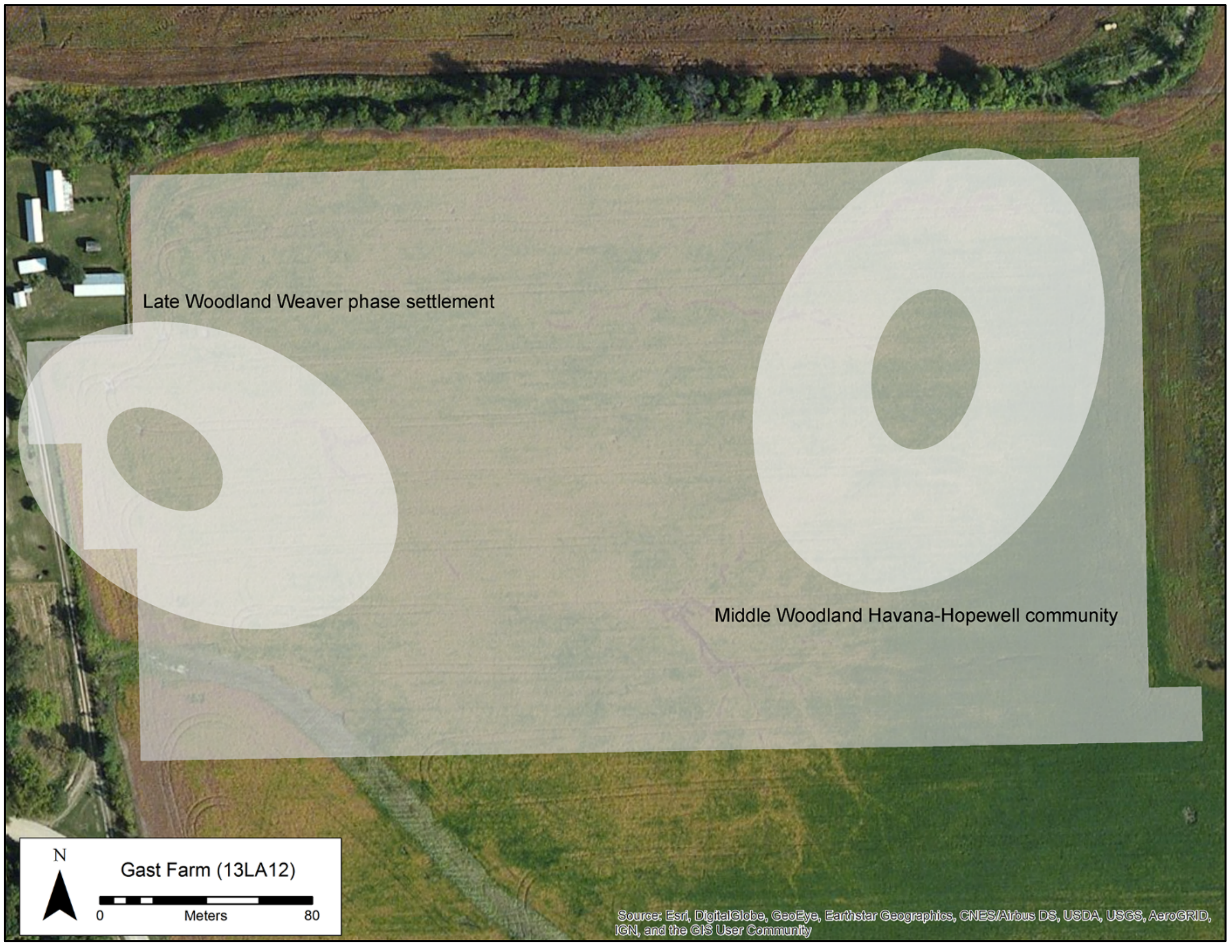

Figure 19. Areas of positive magnetic anomaly concentrations, which indicate the approximate layouts of the Middle and Late Woodland settlements at Gast Farm (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

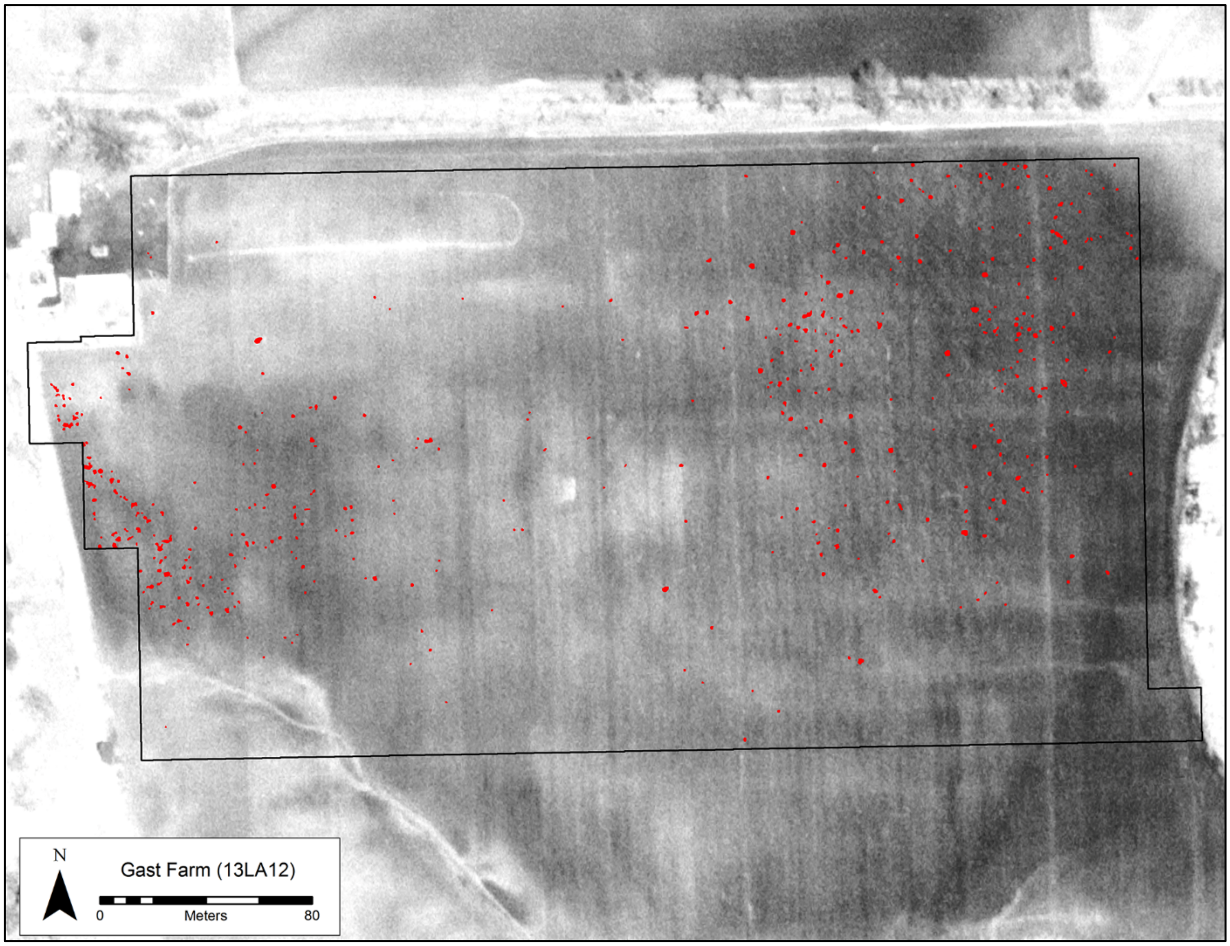

Figure 20. Comparison of positive magnetic anomalies (marked with red) and soil marks in an April 27, 1964 black-and-white aerial photograph (AR1VBAD00010043). The relationship between midden staining and magnetic anomalies is apparent for the Late Woodland Weaver phase occupation to the west (Aerial photograph available from the U.S. Geological Survey).

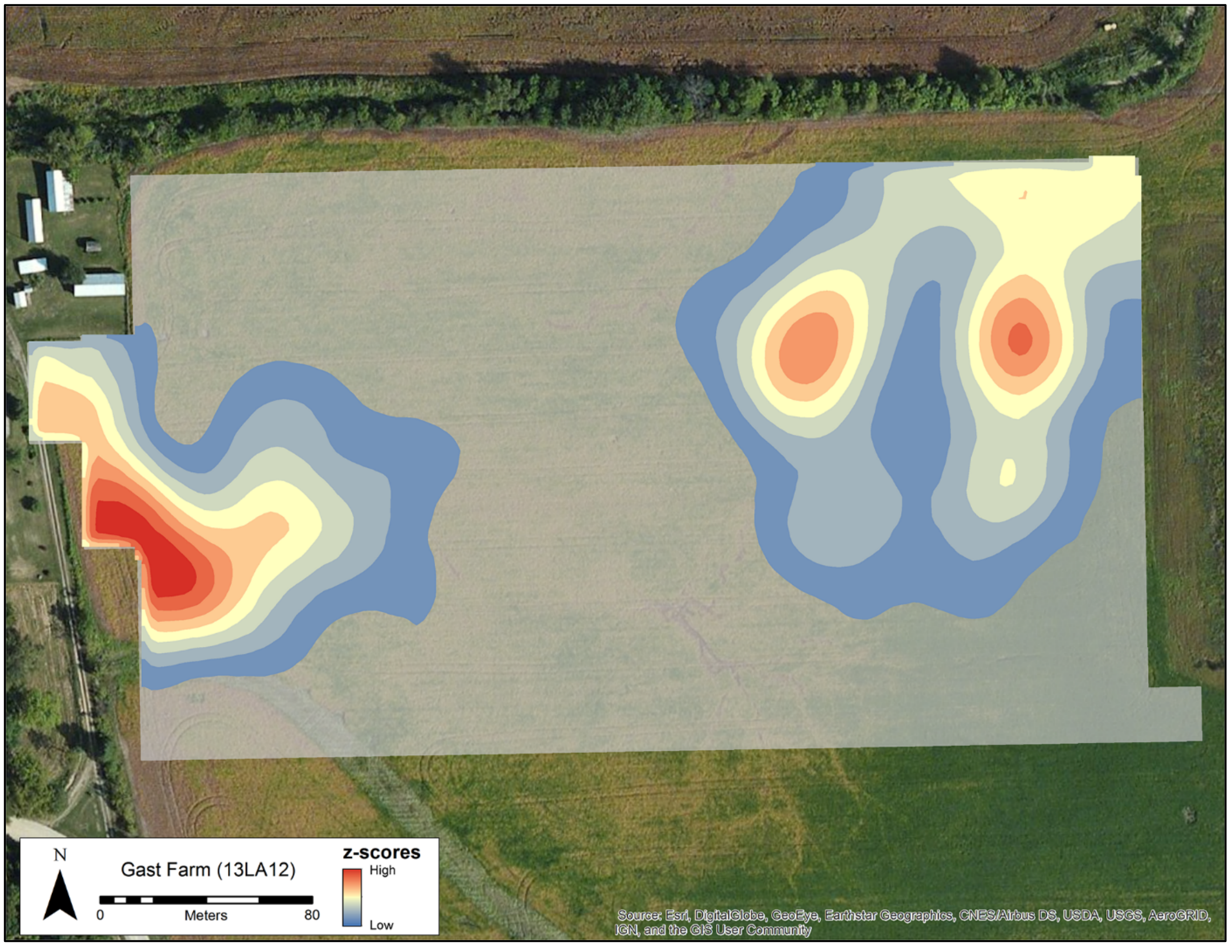

Figure 21. Interpolated and smooth results of a Getis-Ord Gi* test, which indicates statistically significant clusters of positive anomalies (red) in the magnetic dataset (Aerial photograph source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

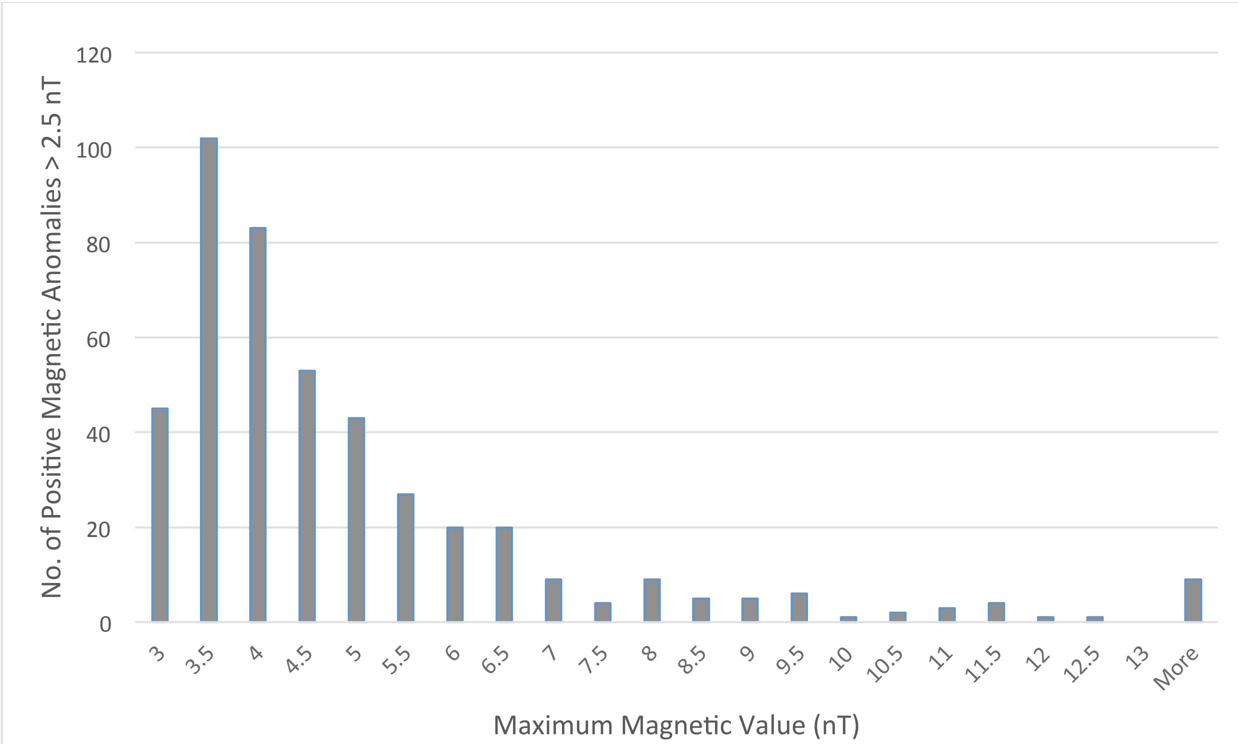

Figure 22. Histogram illustrating counts of positive magnetic anomalies by their maximum magnetic readings.

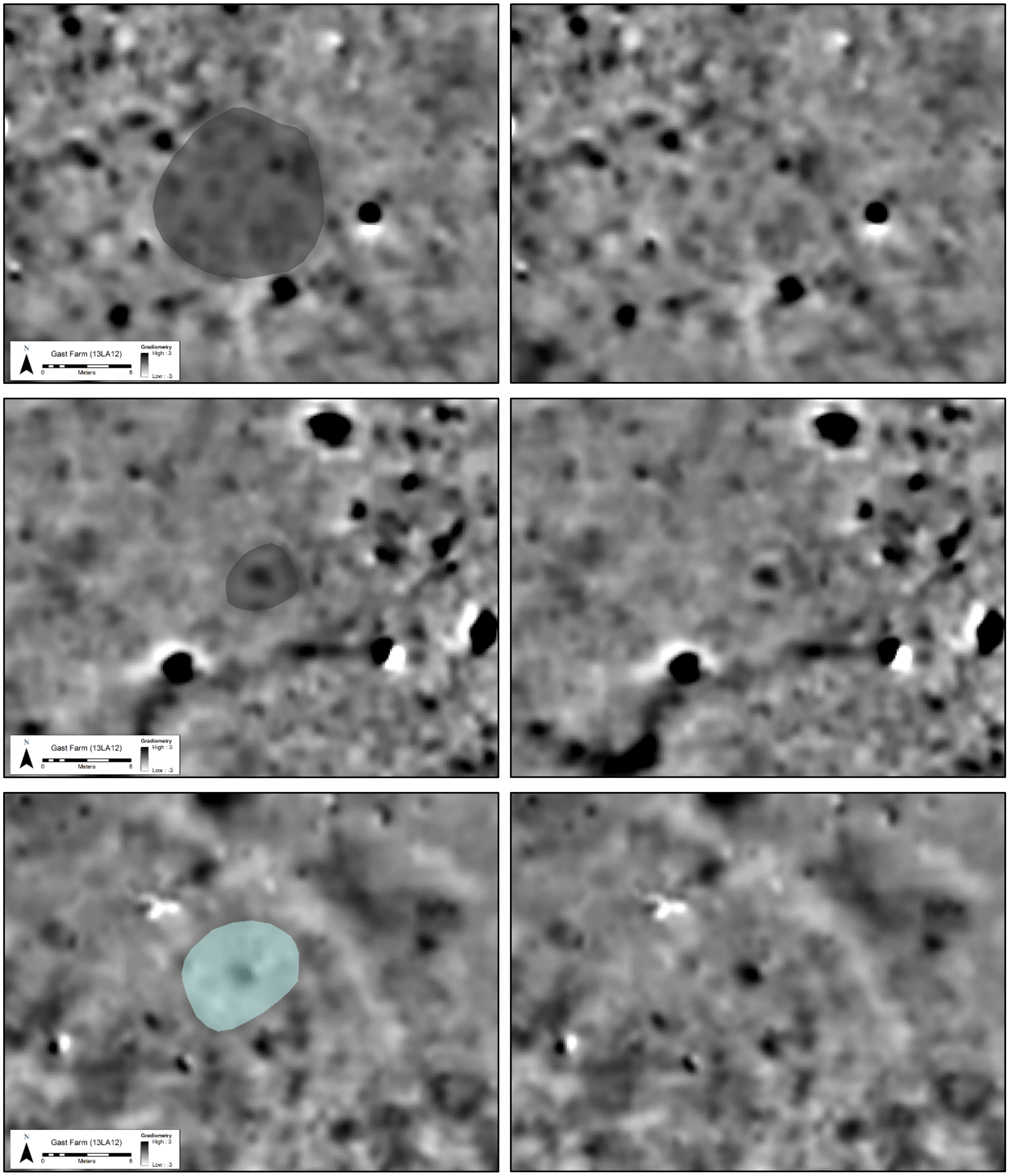

Figure 23. Examples of potential architectural features within the Middle (top and center) and Late (bottom) Woodland components at Gast Farm.

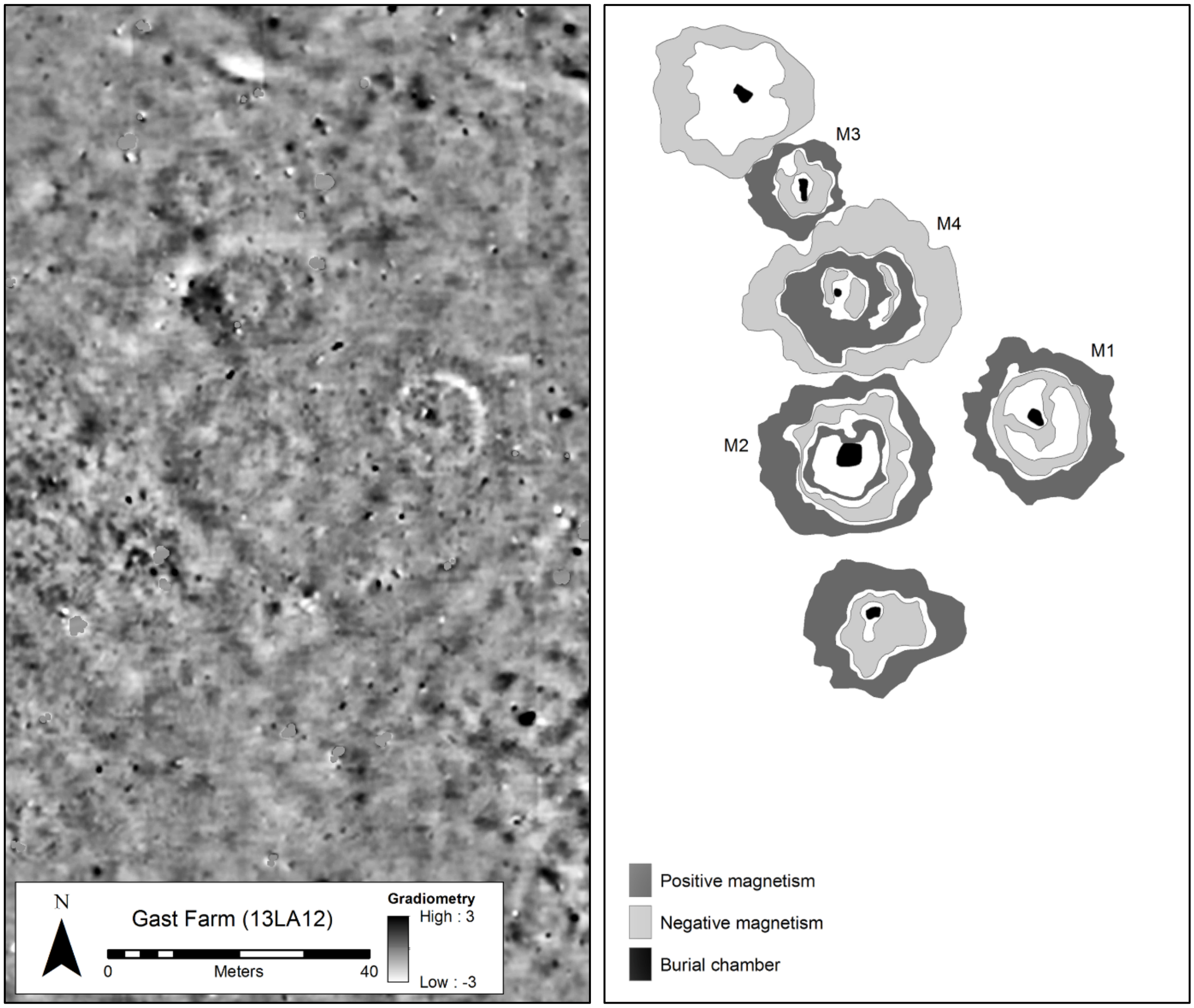

Figure 24. Magnetic gradiometry results (left) and interpretations (right) of the mound group at Gast Farm. Mounds are numbered in the order they are introduced in the text.