Geophysical Survey at the Cahokia Site, May, 2003

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R. Berle Clay
Cultural Resource Analysts, Inc.

Introduction

From May 17 through May 23, 2003, the author with the assistance of staff of Cultural Resource Analysts, Inc., workshop participants, and in cooperation with Dr. Rinita Dalan of Minnesota State University, collected near-surface geophysical data at the Cahokia Mounds State Historic Site in Illinois. This work, in connection with the National Park Service workshop, "Current Archaeological Prospection Advances for Non-Destructive Investigations in the 21st Century," combined electromagnetic (mS/m), magnetic (nT), and magnetic susceptibility data in the exploration of two portions of the larger historic site known vernacularly as the "east palisade, Ramey Tract," and the "west palisade" in the vicinity of the Twin Mounds.

The results of these investigations are reported below. They identified a major conductivity feature in the east palisade area that remains currently unexplained and magnetic features nearby. The geophysical characters of all were further explored by Dr. Rinita Dalan with down-hole measurement of magnetic susceptibility (Dalan 2003). In the west palisade vicinity they confirmed with EM data a pattern of geophysical variation first noted by Dalan (Holley et. al. 1993), also using EM data although a different data collecting strategy, and later by Lowry using resistivity. Limited conventional investigations associate this variation with one or more palisades constructed in this portion of the site. In addition, magnetic gradient survey in the same west palisade area identified possible period features, some of which, although not all, seem to be directly associated with palisade construction. The magnetic characteristics of one of these features were explored by Dr. Dalan using down-hole measurement of magnetic susceptibility.

The author would like to thank the following for making this work possible. In the field he was assisted by Jon Kerr, Grant Day, Andrew Martin, and Brian King, archaeologists with Cultural Resource Analysts Inc., who donated their time to assist in data collecting, and CRAI that covered some of their travel expenses and, importantly, the geophysical survey technology that made the effort possible. The interest and participation of various workshop participants added much to the fieldwork. Dr. John Kelley of Washington University, St. Louis, was most helpful in delineating survey areas on this large and complex site, informing the author of previous work done in them, and

providing copies of relevant field reports. Dr. Michael Hargrave of the United States Army, Engineer Research and Development Center, Champaign, Illinois provided access to his intensive geophysical data sets for the east palisade tract and a much appreciated running dialogue during the preparation of this report which benefits from his knowledge of the site as a whole.

Most importantly, Dr. Rinita Dalan took the time to link her research in the recording and interpretation of magnetic susceptibility through down-hole measurement, in which she is pioneering, with the near-surface data collecting directed by the author. The result is a powerful demonstration of the dynamic that can be produced by the integration of multiple geophysical survey techniques in archaeological fieldwork (cf. Clay 2002). Finally I would like Dr. Bruce Bevan and Dr. Steve DeVore and the staff of the Midwest Archaeological Center of the National Park Service who made the whole workshop possible.

The West Palisade Survey

The first area of interest was in the vicinity of recent "west palisade" studies conducted under the auspices of the Central Mississippi Valley Archaeological Research Institute (Trubitt 1998, 2000, 2001, Trubitt and Baumann 2002). EM and magnetic gradient data were collected in an area bisected by the W80 meter line between W60 meters and W120 meters and between S320 meters and S480 meters. One anomaly identified in the magnetic survey was further sampled by Rinita Dalan with down-hole measurement of magnetic susceptibility together with an area adjacent to it, but outside the anomaly.

This area has been the focus of several studies using geophysical survey techniques and conventional archaeological investigation and a picture is emerging of a series of palisades lines through it trending north/south that probably marked the SW side of the enclosed "grand plaza" to the north and east. The first near-surface geophysical data, in the form of a series of EM transects, were collected by Dr. Rinita Dalan using EM technology (Holley et. al. 1993). This survey effort produced considerable evidence for the structure of the grand plaza and reinforced the suggestion that the development of the plaza was accompanied by extensive anthropogenic landscape modification (Holley et. al. 1993: 316).

More recent, Suzanne Lowry has conducted geophysical surveys in the west palisade area (1998, 1999, 2000, 2001). Concentrating on a low, topographical ridge which is present in the west palisade area, she has completed multiple resistivity transects across the ridge in an effort to explore its structure. These have been accompanied by geological coring and archaeological excavations at selected locations to further explore her findings. Her comments on the nature of the ridge should be repeated:

> "Ridge fill is linear and purposely constructed with a thick peak, which is easily tracked by resistivity transects, even though the topography may reveal nothing or may disagree. *The resistivity peak seems to accompany palisade trenches. The fill is seen as a high-resistivity area, whereas trenches provide a low-resistivity anomaly in the ridge fill* (emphasis added). Therefore, locating the ridge fill provides a good method of locating possible palisade

> trenches. Coring is a good accompaniment to the resistivity transects and excavation is the ultimate confirmation."

Excavation across this ridge has identified multiple wall trenches and these suggest several periods of palisade construction seemingly associated with palisade renewal although it is entirely possible that wider survey efforts will reveal construction episodes signaling substantial changes in palisade alignment. Still, Lowry carefully points out that "this is not to say that all ridges contain palisades or that all palisades were built on ridges." Alternatively, resistivity ridges could represent "linear fill inside the palisade used to level the plaza or areas of refilled borrow pits. However, linear, deep areas of fill which extend for a considerable distance seem to be promising locations to examine for palisade lines."

Dalan's initial data geophysical data collecting along transects in the west palisade area used a Geonics EM31 earth conductivity meter. The EM surveys reported here used a Geonics EM38 earth conductivity meter (Figure 1) which is considerably more compact and easy to maneuver in the field although more restricted in its depth measurement. Data were collected for this survey in 20-meter squares along transects one-meter apart at 50 cm intervals. The instrument was carried with Geonic's patented handle at a constant height of ca 5 cm above ground surface. The Polycorder 720 data logger was programmed to collect data automatically at .5-second intervals, translating into a walking speed of one-meter per second. In order to avoid the "digital lag" inherent in the digital EM38 that was used, data were collected by walking north to south on parallel transects rather than zigzag transects which would have cut the walking distance in half. While this does not eliminate the real time lag in recording, instrument vs. target, it makes the direction of offset (estimate for this walking speed at ca 50 cm south) consistent in one direction. Despite this, the total time to cover one square producing 800 measurements of mS/m was only about 17 minutes. A virtue of using a device like the EM38 is the speed with which it can cover the ground in contrast to, for example, resistivity survey instruments.

Figure 1. Earth conductivity survey in the West Palisade area using a Geonics EM38 earth conductivity meter.

Data were downloaded from the data logger to a laptop computer and examined as xyz data sets in a Surfer worksheet. The x and y coordinates were then stripped from the files for the individual squares and the files were exported as z values alone (measures of mS/m) to Geoplot 3.00 (Geoscan Research) using a .grd file appendage. All further processing was done in Geoplot 3.00 and the results are presented in Figures 2, 3, and 4.

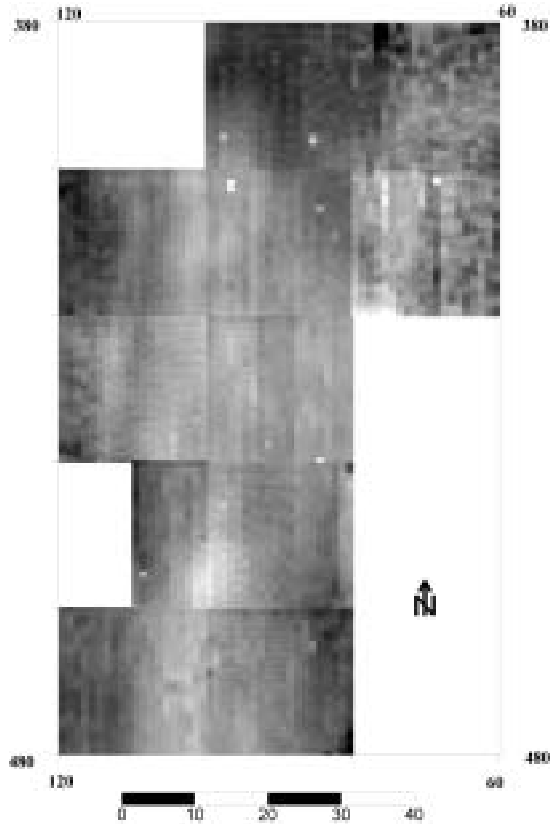

Figure 2. Unprocessed conductivity data (displayed using Geoplot 3.0) for the West Palisade area (dark = higher mS/m, light = lower mS/m).

Because the day was relatively cool (ca. 70 degrees f.) and overcast, the EM38 was carried without any additional insulation. As a result, there were minor differences between 20-meter squares caused by instrument drift (Figure 2). The statistics for the total, 11-square data set were; mean = 59.54 mS/m, s = 5.42 mS/m, and range = 0 to 79 mS/m. The unprocessed data suggest a central portion, corresponding to the “ridge,” in which there is a strong suggestion of linear conductivity “stripes.” This is bounded on the east and west by areas where earth conductivity is seemingly more variable and not striped. On the east side of the survey this would correspond to the inside of the stockade while on the west it marks a lower, moist area which may have been a borrow area.

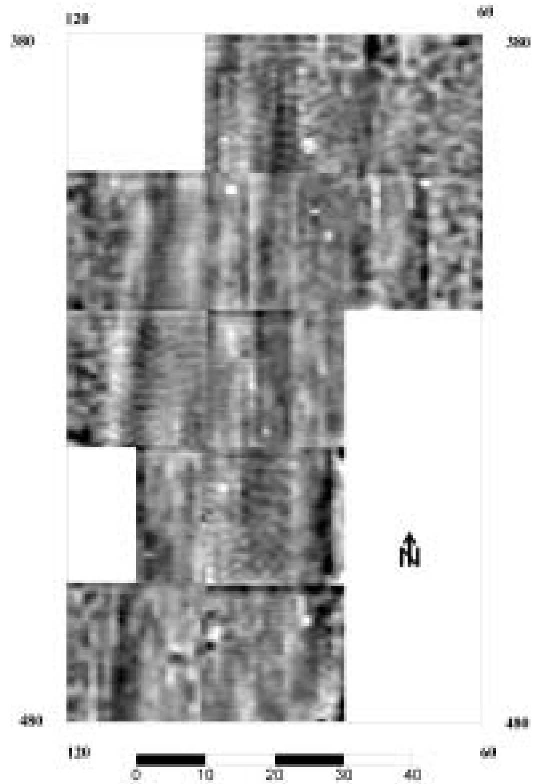

Figure 3. Processed conductivity data for the west palisade survey area (despiking, interpolation of data sets in both directions, and high pass filter).

Data processing in Geoplot 3.0 used the "interpolate" function to double the x and y transects and the "high pass" function to filter the total data set. This has the result of converting the mS/m data to "0-mean" data (Figure 3). The results were then exported to Surfer 8 to add color and grid designations to the data set. The final results are presented in Figure 4 and the 0-mean nature of the filtered data is apparent in the mS/m scale in that figure.

To this figure have been added (in black with the excavation limits marked in dark green) features in the palisade area identified by the excavations of Dr. Kelly of the Central Mississippi Valley Archaeological Research Institute (Trubitt 1998, 2000, 2001, Trubitt and Baumann 2002). In a limited area, archaeological excavation has identified an obvious open-gorge stockade bastion (open to the east) along with segments of one or more stockades suggesting a series of building phases. In the northern portion of the surveyed area, indicated in red, is a feature (discussed below) identified by the magnetic gradient survey that followed the EM survey pictured here.

In Figure 4 "high mS/m" tends towards red, "low mS/m" towards blue. The north/south ridge of lower conductivity, tracked by Lowry as "high" resistivity, breaks down into fairly distinct linear north/south stripes of higher and lower conductivity (lower and higher resistivity). Her work suggests that the fill of the ridge is high resistivity (low conductivity) while the trenches themselves are low resistivity (high conductivity).

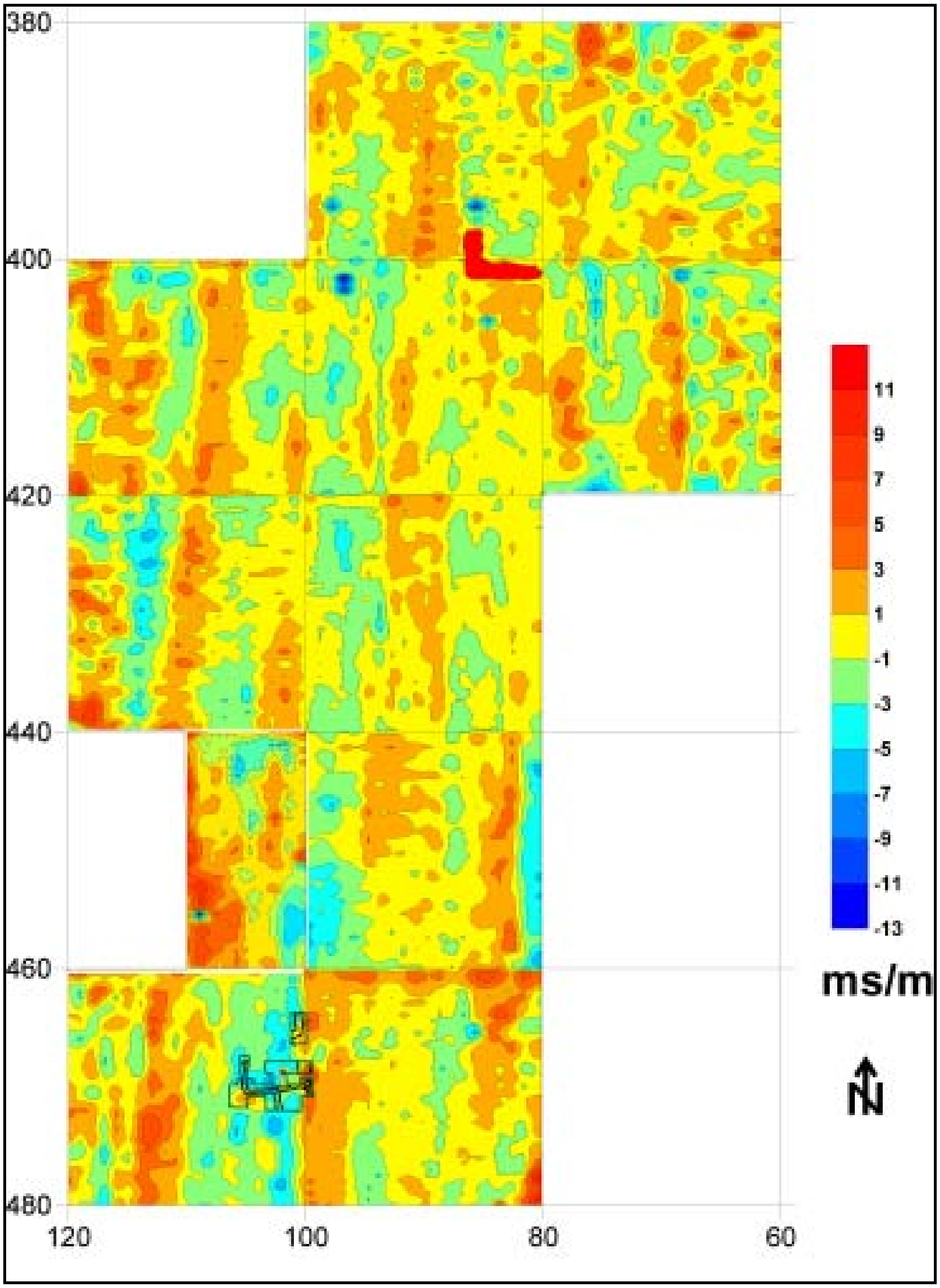

Figure 4. Color-emphasized EM survey results for the West Palisade survey area. Excavated bastion and stockade features are indicated in black and possible bastion identified in the magnetic gradient survey in red.

This striping represents a variation of about 15-20 mS/m and is not great. It is somewhat confused by continuing edge-match problems between adjacent 20-meter squares probably caused by instrument drift during survey. Nevertheless, while the conductivity striping of the ridge is not entirely distinct across the ridge, it does suggest multiple stockade lines separated by substantially lower conductivity "fill." Furthermore, and granted the area of Dr. Kelly's excavation has been disturbed by this work, the open-gorge bastion falls within a prominent lower conductivity stripe which was possibly an appendage of a stockade to the east in a high conductivity stripe. Although less clear, this may also be the case of the feature in the northern part of the survey depicted in red which is possibly another, but burned, open-gorge bastion.

The evidence from the Cahokia West Palisade is reminiscent of possible evidence for fortifications discovered at the Kincaid site in Southern Illinois by the University of Illinois (Cole 1951:54-57). The discussion of the Kincaid "palisade" bears quotation at length.

> "At this point (in the excavation of a trench across a ridge north of the site) the remains of a charred or oxidized post approximately 8 inches in diameter was encountered at a depth of about 3 feet. *Surrounding the post and extending approximately east and west was a band of clay which, except for its irregularity, had the appearance of a wall structure.* Since it was evidently a cultural feature it was labeled "Feature I," and the main east-west trench was cut to expose it. *The field notes state that the mud walls of Feature I showed up clearly against the sand* (emphasis added)."

At Kincaid, it would seem, the line of the palisade of standing posts on the north side of the site was purposefully packed with clay, contrasting with the sand ridge on which it was constructed. When this clay dried, it is surmised, it would have served as a concrete-like foundation setting to the posts of the palisade. At the same time the selective choice of clay for the packing would produce a pronounced resistivity/ conductivity contrast in which the actual wall trench would be marked by low resistivity or high conductivity, similar to the hypothesized geophysical reconstruction of the Cahokia West Palisade.

A magnetic gradient survey (Figure 5) was also conducted in the west palisade area, covering a part of the grid surveyed with the EM38, and including additional area north of the conductivity grid. This survey used duplexed Geoscan Research fluxgate gradiometers. Data were collected on transects one-meter apart at .25 cm intervals. Using the duplexed instruments it was possible to cover an entire 20-meter square in approximately 5 minutes.

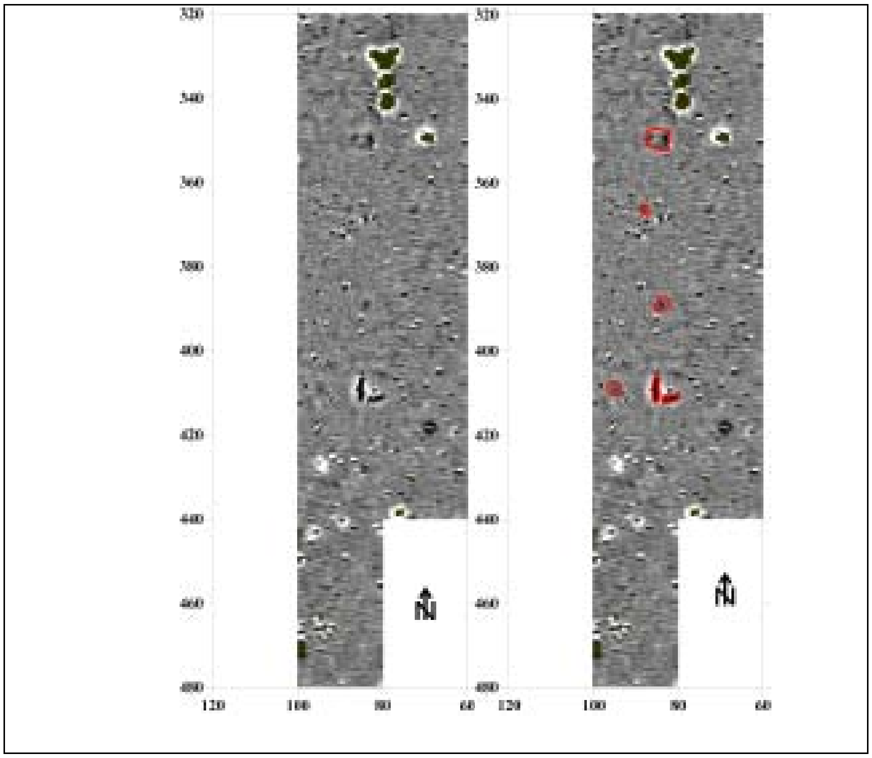

Figure 5. West Palisade magnetic gradient survey. On the left, processed data, on the right, certain magnetic anomalies outlined in red.

Rinita Dalan further explored the northernmost of these magnetic anomalies using down-hole measurement of magnetic susceptibility (Dalan 2003:5-6). A vertical recording of magnetic susceptibility in this anomaly at S349W83, when compared with a coring outside the anomaly at S354.5W80, clearly indicated elevated susceptibility in the anomaly with an abrupt lower termination suggesting a well-defined base to it. These measurements, together with the dark, midden-rich soil from the core, and the “rectangular” shape of the anomaly, suggest that this feature may be a house basin. Given its location on this ridge, possibly over one or more earlier stockades (this area was not covered in the EM survey), it is quite possible that this feature is a late occupation, Sand Prairie Phase house (Dr. John Kelly, personal communication on-site),

The East Palisade/Ramey Tract Survey

The second geophysical survey area was the 2003 National Park Service geophysical workshop grid. This was located just off the northeast corner of Monk’s Mound on a portion of what is known as the Ramey Tract. This portion of the Ramey tract is astride, or near, the hypothetical extension of the inner palisade line as it turns west around Monk’s Mound (cf. Anderson 1969: Fig. 45). It is in an area which slopes down, away from the flat adjacent to the east side of Monk’s Mound (and the location of Mound 36) toward the bottomland and channel of Canteen Creek to the north.

The entire workshop grid (and additional partial and complete 20-meter squares) was covered with the EM38 earth conductivity meter (Figure 6). For this survey the EM38 was carried in an insulating sheet form sheath because the temperature was somewhat warmer than earlier and, perhaps more importantly, because the survey was made in full sunlight. Data were collected, as in the West Palisade survey, at 50 cm intervals along transects one-meter apart. The Polycorder 720 data logger was set to trigger automatically every .5-second and the metronome used to produce a ground speed of one-meter per second. A total of 15,200 readings of mS/m were collected. These had a mean of 47.038 mS/m, s of 16.329 mS/m, and a range between 19.592 and 88.808 mSm.

Figure 6. Jon Kerr surveying the 2003 Workshop grid with the EM38 covered with the sheet foam insulation (Monk's Mound in the background).

The conductivity data were processed in Geoplot 3.0. The "interpolate" function was used to expand x- and y-axis data producing 16 measurement points of mS/m per square meter. A uniform high pass filter with a 10x10 meter radius, followed by a gaussian low pas filter with a 1x1 meter radius, was then applied to the data set. This has the additional effect of converting the mS/m data to 0-mean.

The results of this earth conductivity survey are presented in figures 7, 8, and 9. They revealed the presence of a large, coherent, high conductivity anomaly covering a large part of the workshop survey grid. The footprint of this anomaly covers 2,000+ square meters (its edges have not, perhaps, been fully established with this survey because of high grass to the east and north of the grid, limiting survey in those directions). In its major dimensions it is aligned somewhat off the cardinal points with the result that the sharply marked southern side faces about 15 degrees to the southeast. There is a prominent square extension to the anomaly on the southern side. The eastern side of this survey was conducted in the high grass covering Ramey field outside the mowed area of the workshop grid. A prominent north/south, ragged white line indicates where the EM38 became entangled in wild sweet pea vines.

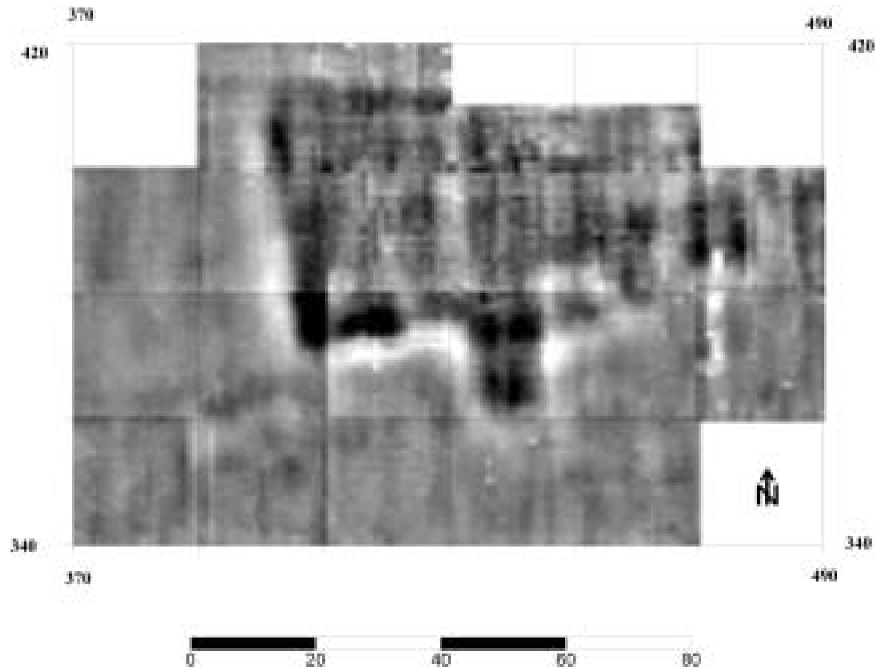

Figure 7. Conductivity survey in the East Palisade vicinity, Ramey Tract.

In Figure 8 these data, exported to Surfer 8, have been contoured and emphasized with color. The image has then been tipped to simulate a perspective view looking to the northeast, away from Monk's Mound.

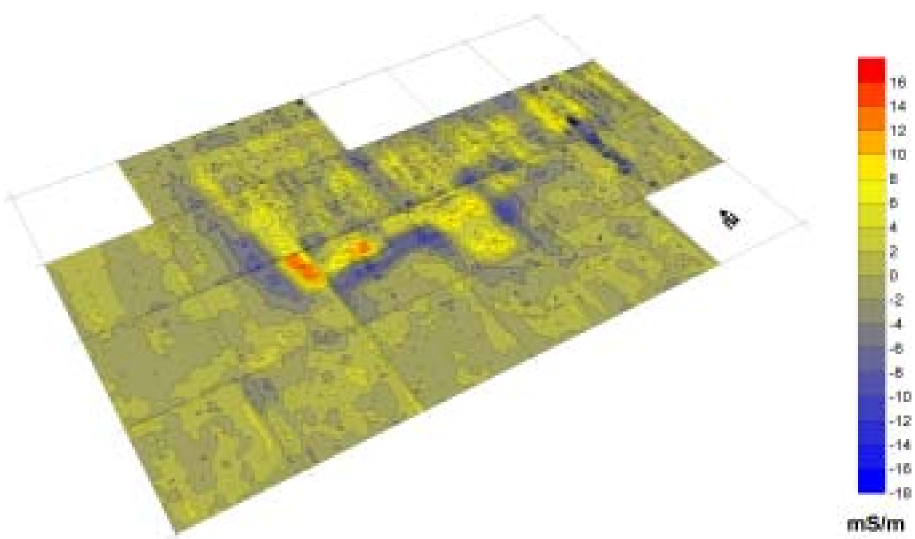

Figure 8. Color emphasized and contoured results of the EM survey of the East Plaza survey grid.

There are major problems involved in the interpretation of this anomaly from these geophysical data alone. Superficially it suggests a plowed down structure platform, perhaps with a ramp facing to the southeast. Most importantly however, there has been no suggestion from any other archaeological research (including archival maps and air photos dating from the early 20th Century) that there ever existed a mound at this location. This would seem to suggest that this is not a feature associated with the prehistoric occupation of the Ramey tract. The alternative is that the feature is historic and, in some sense, associated with the agricultural history of the tract, or possibly with an unrecorded period of archaeological investigation (in which the anomaly would represent fill of an excavation with clayey soils).

Only a portion of the workshop grid—for the most part west of the conductivity anomaly—was surveyed with the fluxgate gradiometer. Two Geoscan Research machines were used, as in the survey of the West Palisade (Figure 9).

Figure 9. Jon Kerr surveying portions of the Workshop Grid with duplex Geoscan Research fluxgate gradiometers.

Data from the magnetic gradient survey were processed in Geoplot 3.0. The merged data set from the two gradiometers comprised 19,200 measurements of nT. These have an unprocessed mean of 0.009 nT, s of 1.439 nT, and range between –72 nT and +68 nT. This range reflects that several metal objects, probably historic, were encountered in the survey. In Geoplot 3.0, zero-mean traverse was used to correct imbalance between the individual data sets, destagger to correct minor pacing errors, despike to minimize the effect of metal “hits,” and interpolate along the x dimension to raise data density to twenty-four readings per 20-meter square. A gaussian low pass filter with a 1x1 meter radius was then used to smooth the output (Figure 10).

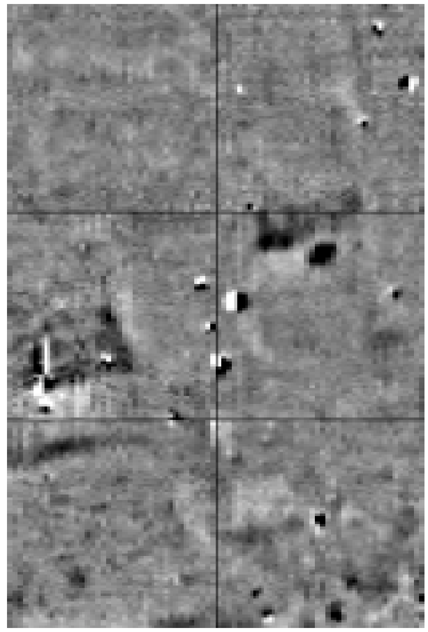

Figure 10. Magnetic survey of portions of the East Palisade in Ramey Field. Dark values are high nT, light values, low nT.

A number of anomalies are apparent in this data set, all of them just west of the conductivity anomaly identified with the EM38. Scattered "dipole" signals surely indicate historic iron. The following series of figures (Figs. 11 to 13) highlight these magnetic anomalies and relate them to the conductivity survey. To do this, the data have been transferred from Geoplot 3.0 to Didger 3.0 (Golden Software), then back to Surfer 8 for the final graphic.

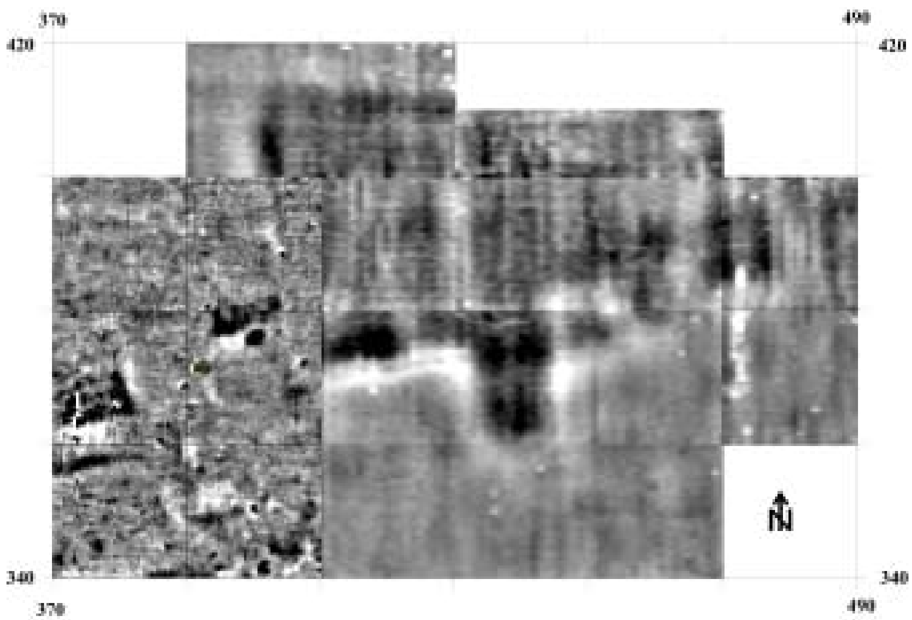

Figure 11. Results of the magnetic gradient survey related to the earth conductivity survey.

In Figure 11 the two survey areas are related. Of special importance is the fact that the conductivity anomaly so prominent in mS/m only faintly registers in the magnetic data set. This example stresses the point made elsewhere (Clay 2002) that these two forms of survey complement each other and should not be considered "competing" forms of survey.

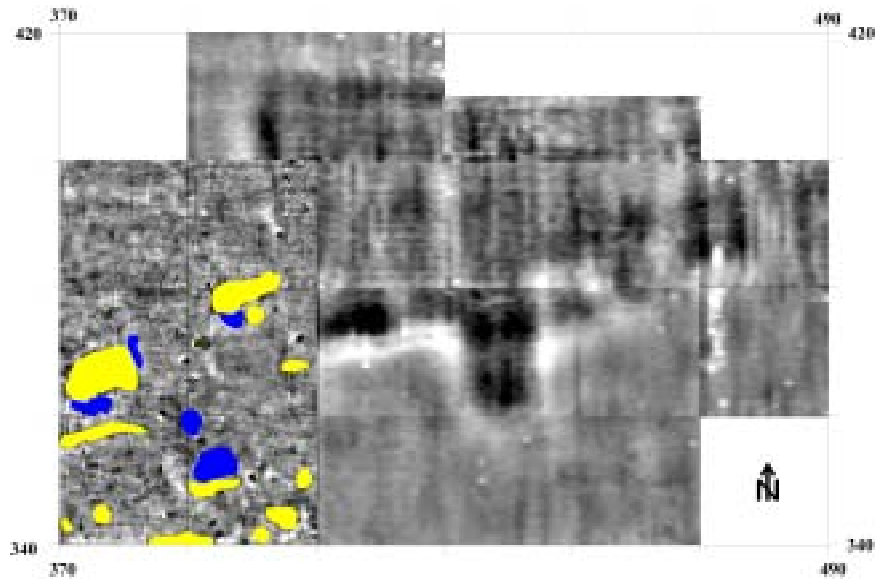

Figure 12. Highlighting the possible features apparent in the magnetic data (yellow = high nT, blue = low nT).

Figure 12 highlights some of the high and low magnetic anomalies. Disregarding the intense magnetic dipoles (not indicated in Figure 12) which have probably been caused by scattered historic metal, the "high" (yellow) anomalies appear as concentrations of elevated magnetic susceptibility (all less than 17 nT). The "lows" indicate coherent areas where nT is generally between 0 and –17 nT. It is very possible that the two rectangular areas of elevated nT represent midden filled house basins. Of these, the one on the right may have been truncated by the conductivity anomaly and this might argue that the conductivity anomaly post-dates the magnetic features and, possibly, is historic.

Finally, in Figure13 the locations of the magnetic anomalies are superimposed on the gray scale image of the conductivity values. This figure emphasizes the reverse of Figure 12 above, demonstrating that the magnetic anomalies are not registered with the conductivity data. Again, the two survey methodologies complement one another nicely in this example.

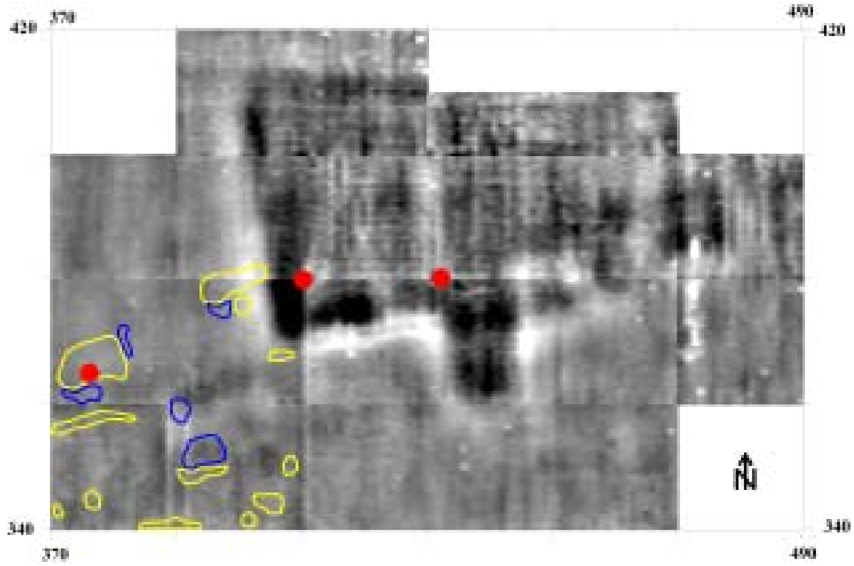

Figure 13. Magnetic anomalies superimposed on conductivity data. Red dots indicate locations of down-hole measurements of magnetic susceptibility in anomalies by Rinita Dalan (a sample was also taken outside the large conductivity anomaly).

Following this initial survey, Rinita Dalan did exploratory down-hole measurements of magnetic susceptibility both in- and outside the major conductivity anomaly and in the western-most area of elevated magnetic susceptibility located by the magnetic gradient survey (2003: 7-8). These measurements demonstrated consistent contrasts in vertical magnetic susceptibility between the conductivity anomaly and surrounding soil matrix and, for the magnetic susceptibility feature, a well-defined base suggesting a midden-filled house basin.

Summary Comments

Geophysical survey in these two portions of this large, complex archaeological site emphasizes once again (following the work of Dalan, Lowry, and Hargrave) the important role which geophysical data technology can play in developing an archaeological understanding of such a site. In these two instances, combining three data collecting techniques, considerable information can be obtained directly related to the *tactical* conduct of archaeological research. This is to say, that these two examples have focused in on specific areas of the site that pose specific interpretive problems. In both sections of the site, the data presented here permit the rather precise formulation of problems to be addressed by other types of field investigation. The value of these two demonstrations, it must be emphasized, lies in the manner with which they are both driven by and remain linked to ongoing, traditional research.

There is another aspect of geophysical research, what I would call *strategic* research, which operates at a different level. Dalan has demonstrated in her earlier EM surveys at Cahokia (Holley et. al. 1993) the collection of geophysical data at what I would call a *strategic* level, focusing on large-scale problems of site definition and understanding, in her case the Grand Plaza (Dalan elsewhere (1993) deals with this same issue, but in different terms). Quite often this level of geophysical survey can involve larger questions of soil physics, at first glance unrelated to archaeological specifics but ultimately of interpretive significance. Michael Hargrave is currently conducting extensive magnetic surveys of the Ramey Tract, representing another level of strategic data collecting. At this level of data collecting, because of the scale of the areas that are covered, geophysical data interpretation tends to work well ahead of more traditional archaeological fieldwork which focuses on a much narrower spatial scale. As such it can generate its own research problems that are equally valid. Less thought has been given to this level of data collecting in United States practice.

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