Application of Geophysics to North American Prehistoric Sites

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Introduction

Archaeological geophysics, sometime called remote sensing by archaeologists, is the measurement of geophysical properties at the ground surface to create images of the subsurface that can be interpreted by a geophysicist and archaeologist working together to identify subsurface features of cultural origin. As such, geophysics is a tool to infer the presence of cultural features before excavations actually take place. Geophysical measurements also allow for obtaining a continuity of subsurface information that compliments the detailed point information from shovel tests or unit excavations. The geophysics can then provide context to the excavations made by the archaeologists.

Geophysical measurements are not routinely obtained at North American prehistoric sites. This situation contrasts with European practice, where geophysical studies are a routine part of archaeological investigations. A contributing factor for this situation is the subtlety of North American targets. There is a perception by many archaeologists that because prehistoric peoples in North America did not routinely leave massive stone foundations, there is little to image with geophysics. Another factor is that professional geophysicists have not been involved with the majority of the available case histories. Even the case histories published at the North American Database of Archaeological Geophysics (NADAG) at the University of Arkansas (http://www.cast.uark.edu/nadag/) are not of uniform quality. Of the approximately 80 results of geophysical surveys presented for prehistoric sites by NADAG, more than three quarters do not demonstrate representative results and/or appropriate procedures. Nevertheless, within this group there are also some excellent case histories. Especially worthy of note are recent studies conducted at the Hollywood Mounds site in Tunica County, Mississippi by the University of Mississippi (Johnson et al., 2000); the Mit-tutta-hang-kush Village (Fort Clark State Historic Site, 32ME2), ND presented by Kvamme (2001); and the Double Ditch Indian Village State Park, ND (32BL8) presented by Kvamme (2002). Many of the results of the geophysical surveying appear to indicate promising results, but have not been ground-truthed, such as the work at the Greenbriar site in Arkansas (Johnson et al., 1999). The work by the University of Arkansas at the Toltec Mounds (Lockhart, 2001) shows interesting results that could also benefit from additional ground truthing.

In spite of the poor results indicated by most of the available case histories and common negative attitudes, prehistoric sites are often good targets for high-resolution geophysical surveying. Human occupation creates many types of changes and disturbances in properties of natural soils and sediments at an archaeological site. Examples of common archaeological targets at prehistoric sites can include:

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- Fire hearths – magnetic and electrical resistivity highs
- Paths, roads – of variable electrical response, depending on soil type; usually best marked by magnetics: can be magnetic highs if associated with the placement of stone, but most paths and roads appear as magnetic lows because of the disruption of the natural magnetic fabric or simply the creation of a buried topography, similar to the effect of plow furrows, which are also well imaged by magnetics
- Compacted earth floors – conceptually these should have a relatively high resistivity, but where mapped and ground-truthed, earth floors are usually marked by low resistivity anomalies. This is interpreted to be due to the compaction inhibiting the infiltration of rainwater, allowing for water to accumulate at the top of the floor. Compaction may also lower the elevation of a floor, allowing water to accumulate once the house structure is removed.
- Filled post holes - relatively low electrical resistivity; commonly relatively high magnetic response as filling is from surficial soil that tends to be more magnetic
- Pit features and graves – Ground Penetrating Radar (GPR) often works well to image disruptions in the fabric of natural soil associated with excavations, as well as imaging objects within the excavation; disruption of natural soil fabric can cause magnetic lows; soils in a grave shaft or pit feature are usually not as compact as surrounding soils, may have a higher organic content and can retain a higher moisture content such that they are marked by resistivity lows.

For many investigations, the best results are obtained when more than one technique is applied to the problem. For example, a combination of magnetics and DC resistivity is often effective as a means to map the limits of cultural resources in advance of excavations. Disruptions to natural soil layering are frequently best delineated with GPR.

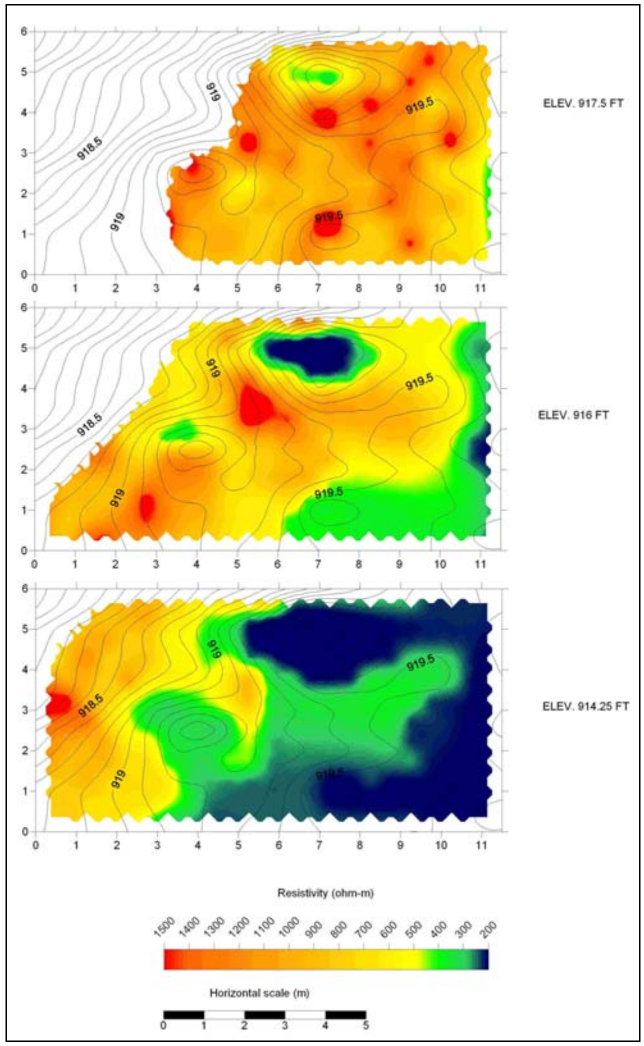
The ability for geophysical surveys to provide useful information is better than it ever has been. The physics of archaeological features hasn't changed. Most geophysical techniques have been around for many years. Basic interpretation strategies also haven't changed, as interpretations are based on an understanding of the physics involved. What has changed is the ability of the geophysicist to gather data rapidly. Also, better computers and improved software have revolutionized the means by which data can be processed and presented, resulting in improved interpretations. Methods, such as resistivity cross sections and 3D resistivity imaging, which are not normally used at archaeological sites, are now relevant. Examples of this are presented at several of our recent case histories.

Case History No. 1 – 3D Resistivity Imaging of Mounds, Ohio River Terrace near Pittsburgh, PA

A field of more than 100 mound structures associated with the presence of Adena points in their immediate vicinity was recently identified along a terrace of the Ohio River north of Pittsburgh, PA. These mounds are not part of any previously designated site, but were identified on property where oral history indicates that the original landowner recognized that the mounds represented burials and planted crab trees over the site to prevent access. As such, the site has never been included in any inventory of mound structures.

A geophysical survey was conducted in 2004 to image the interior of some representative mounds to assess if they did actually contain features consistent with their being burials.

Resistivity measurements were made with a Syskal Jr. multi-electrode system because this technique offers the possibility of imaging the mound in three dimensions. Measurements were made with the Wenner configuration with an electrode spacing of 0.5 m and a line spacing of 0.5 m. The data were processed with the RES3DINV program, which accounts for topography and can present the results in terms of resistivity at different elevation slices (shown as feet above MSL with horizontal dimensions in meters as shown on the attached images). The results of this analysis indicate that a low resistivity zone consistent with the dimensions of an individual burial is present beneath the most prominent mound centered at 7m E – 5m N on the attached images. A resistivity low slightly off center from an apparent mound structure crest is present at 3.5m E – 3m N. Burial mounds in Western Pennsylvania may have a rock core or a burial pit (shallow shaft) dug into the original soil, both commonly associated with resistivity lows. Soil within grave shafts or pits is often less dense with higher moisture content than the surrounding undisturbed soil resulting in resistivity lows. Boulders or cobbles are usually highly resistive and can also result in measured resistivity lows.



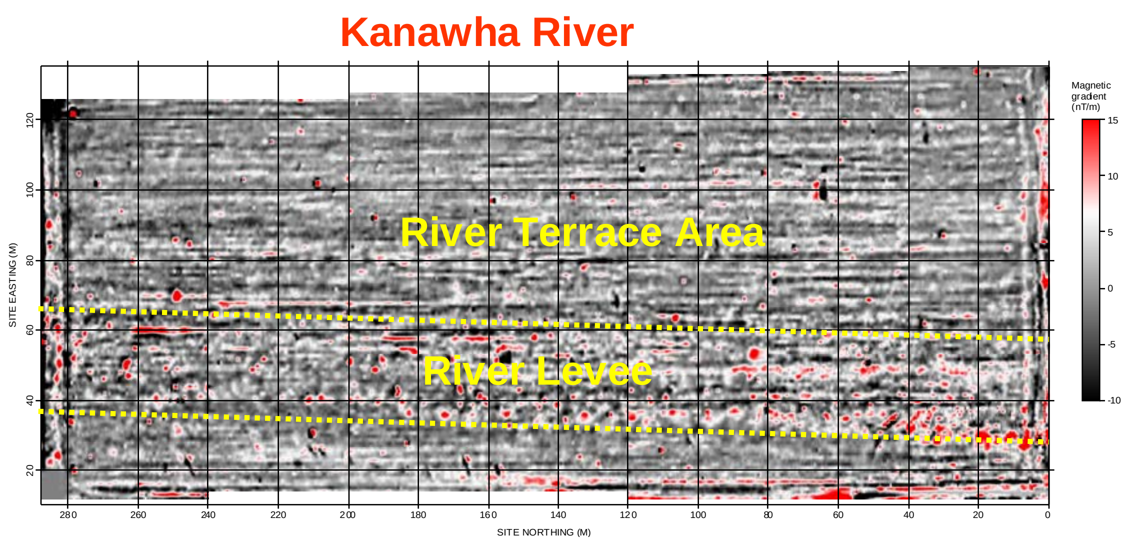
Elevation slices of ground resistivity through mound structures based on 3D analysis – the presence of a zone of low resistivity zones consistent with the dimensions of individual burials supports the archaeological interpretation that this area is a prehistoric cemetery.

Case History No. 2 – Archaic to Late Woodland Settlements, Kanawha River Terrace, Putnam County, WV

The scope of this 2003 investigation conducted on behalf of Horizon Research Associates of Morgantown, WV was to apply geophysical technology to identify possible prehistoric cultural features in a 10-acre (4 hectare) site adjacent to the Kanawha River, West Virginia. The property was being considered for development by the Putnam County

Development Authority (PCDA). Phase I level archaeological studies over the entire property were conducted in the 1990s and prior to this study the northern part of the site had been identified as site 46PU159. The Phase I survey encountered 1,036 artifacts from systematic collection at 171 locations and five trenches.

Three geophysical techniques were applied: magnetic gradiometry, and DC resistance, and DC resistivity profiling. Magnetometer data were collected with two separate systems: a Scintrex Smartmag and an EG&G Model G-858G cesium vapor gradiometer. Readings were made at a rate of 10 per second (an average spacing of about 11 cm) resulting in the acquisition of approximately 310,000 measurement points. Resistance data were gathered with a Geoscan RM15 resistance system every half meter along north-south transects 1 meter apart in 20-meter grids. A total of 36,280 measurements were obtained in this manner. The RM15 was configured to obtain measurements from both a 0.5 and 1 meter electrode spacing using a multiplexer. Three resistivity profile data were obtained by laying out the 24 electrodes at one-meter intervals and the measurements taken automatically with the Syscal Kid multi-electrode resistivity system. A fourth line was taken with a 3-meter electrode spacing. The Syscal Kid was programmed to use the Wenner array with as many as 7 multiples to the initial electrode separation.

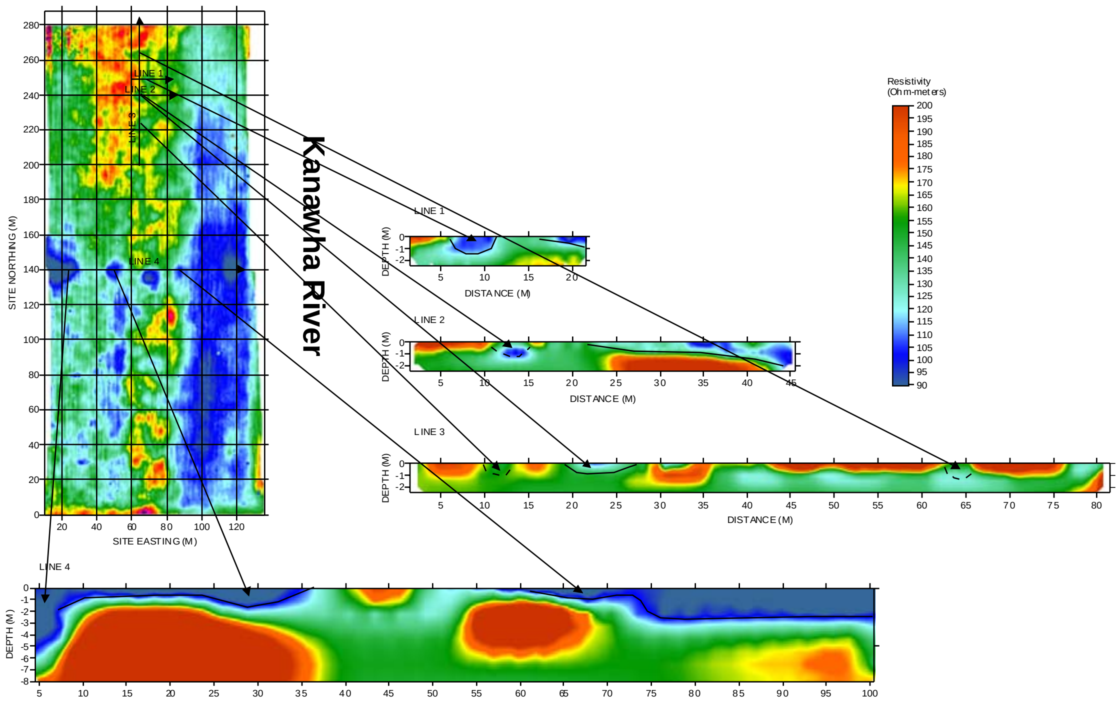


Magnetic gradient across Putnam County site – magnetic highs interpreted to be mainly fire hearths – confirmed where excavated – lineations are plow furrows

The fundamental observation is that most of the geophysical anomalies interpreted to be of cultural origin are located on or near the top of a levee shown above. The flat terrace surface on the river side (east side) of the levee is relatively featureless. The E-W resistivity profiles indicate that the terrace area is a soil of lower resistivity (probable higher clay content) that drapes over a higher resistivity soil that appears to be contiguous with the soil at the top of the levee. The thickness of the terrace soil in the eastern part of the area investigated is about 2.5 to 3 meters. This suggests that younger sediments cover an older land surface where additional evidence of settlement could be encountered.

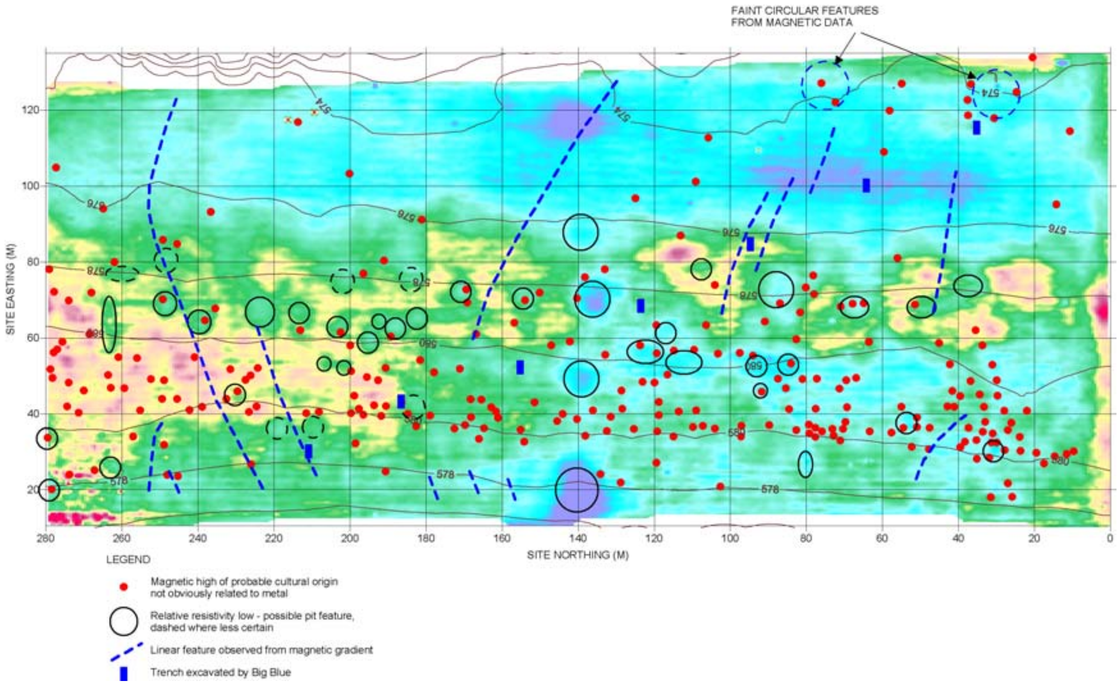
As levees are formed as overbank deposits under flood conditions, it is not unexpected that the levee would have a higher sand content and a corresponding higher resistivity than the lower terrace area. This situation can be observed from the RM15 resistance data in the area north of about 180 meters N. In this area the relatively high resistance values correspond closely with the crest of the levee. South of about 180 meters N, however, the highest resistance values follow a band on the eastern slope of the levee and not on the crest itself. This pattern does not have an obvious geologic origin and leads to the speculation that the overall pattern has been disturbed by human occupation.

Most of the magnetic highs are interpreted to be fire hearths, as the anomalies do not appear to be associated with metal. A significant observation from the resistance measurements is the presence of 43 discrete low resistivity anomalies. These are interpreted to be pit features or earth floors. Where crossed by the resistivity profiles, the smaller features appear to be pits as deep as 1 – 2 meters. Some of the features are very large, suggestive that they are more likely to be house floors.



Soil resistance mapping from RM15 compared with resistivity profiles obtained with Syskal equipment – note this figure is rotated counterclockwise with respect to magnetic gradient map – the results define the depth of what appear to be pit features and also indicate that there is a buried terrace surface on the eastern side of the site next to the Kanawha River

The results of the magnetic survey also identified the location of test trenches from the previous investigations in the 1990s that were excavated along a diagonal line across the site. Only one of these trenches intersected a geophysical anomaly (which was interpreted to be a pit feature). This is the only trench that encountered cultural material.



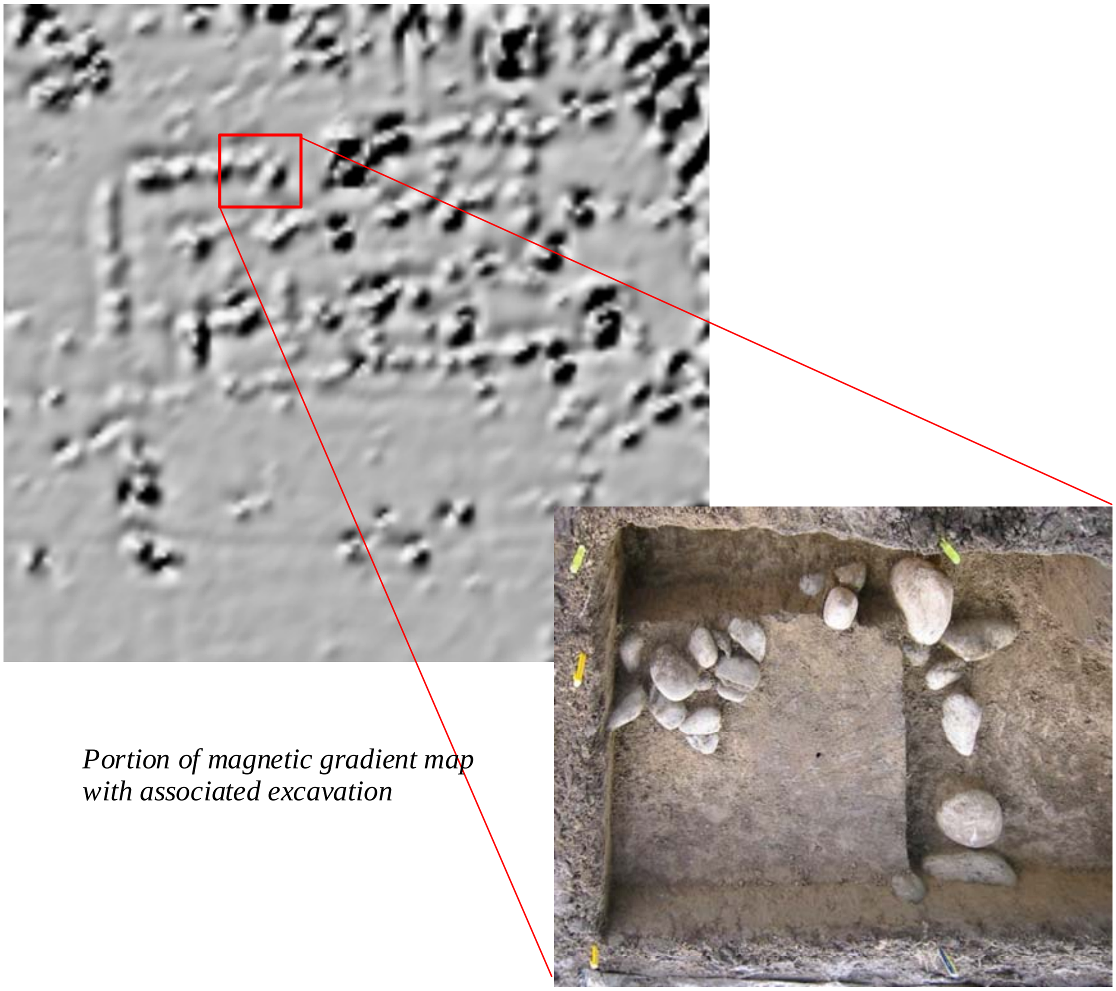
Overall interpretation of Putnam County geophysical data – unit excavations over points interpreted to be fire hearths proved to be fire hearths; the magnetic results also allowed for the location of the Phase 1 test trenches – only one of these trenches was located over a geophysical anomaly interpreted to be a pit feature. A pit feature was identified at this location.

Case History No. 3 – Aztec Ruins National Monument, LA 1674

This project was undertaken as one part of a series of activities related to the realignment of Ruins Road along the eastern and southern boundaries of the National Monument. The realignment is necessary because vibrations from vehicular traffic are endangering the structures at Aztec Ruins. The proposed alignment of the road will traverse LA 1674.

Two geophysical techniques were applied. The first was the measurement of magnetic intensity and gradient with a Geometrics Model G858G magnetometer with gradiometer option. The second was the measurement of ground resistance with the Geoscan RM15 twin probe resistance system. Three areas were selected for testing based on the geophysical data.

The magnetometer survey provided more definitive results than the resistance survey and identified several previously unknown structures at the site. Two of these structures were tested by unit excavations. The structures that were best defined by the geophysical surveys are shown here. The data indicate two adjacent six-room structures. The corner of one of the structures was tested by Excavation Block 1 to determine whether there were two separate structures or one large one. The excavations showed that they were not connected. A plaza may be present along the south side of the structures.



Portion of magnetic gradient map with associated excavation

The use of the geophysical survey not only mapped several structures, but made it possible to use a very limited excavation program to answer specific questions regarding the nature of the structures.

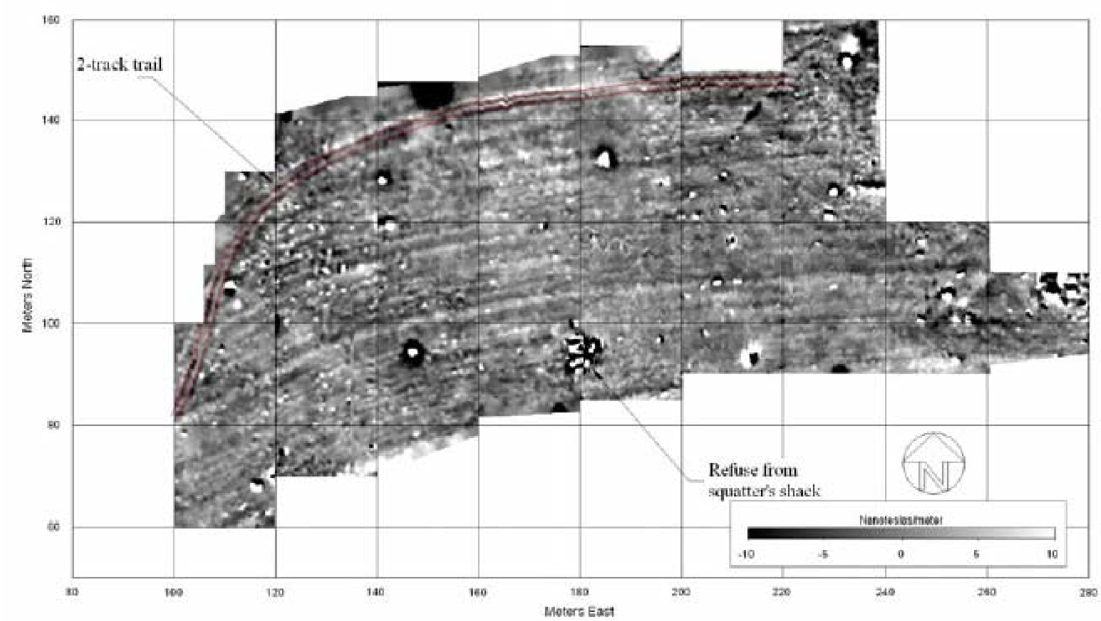
Case History No. 4 – Silvernale Site, Redwing, MN

Silvernale is one of the earliest and largest of at least nine large village sites inhabited between ca. A.D. 950 and 1400 at the junction of the Cannon and Mississippi rivers. Between ca. A.D. 1050 – 1250 (known as the Silvernale phase), inhabitants of the Red Wing Locality participated in intensive interaction among several regional cultural traditions. This phenomenon resulted in a localized cultural development that is unique to the sites in the locality and that has been an ongoing source of anthropological research for the last 55 years (Johnson, et al., 2003).

Two geophysical techniques were used to define the distribution of subsurface features at Silvernale:

- Total magnetic field and vertical magnetic gradient measured with an EG&G Model G858G magnetometer/gradiometer, and
- DC resistance measurements made with the Geoscan RM15 resistance system.

Magnetometer data were collected along north-south transects 0.5 meters apart. Readings were made at a rate of 10 per second resulting in an average spacing of about 11 cm. Data were collected in blocks of 20x40 meters or larger. Vertical gradient and total field maps were prepared after various editing and processing steps. The most apparent characteristic of the vertical gradient data are the linear responses caused by

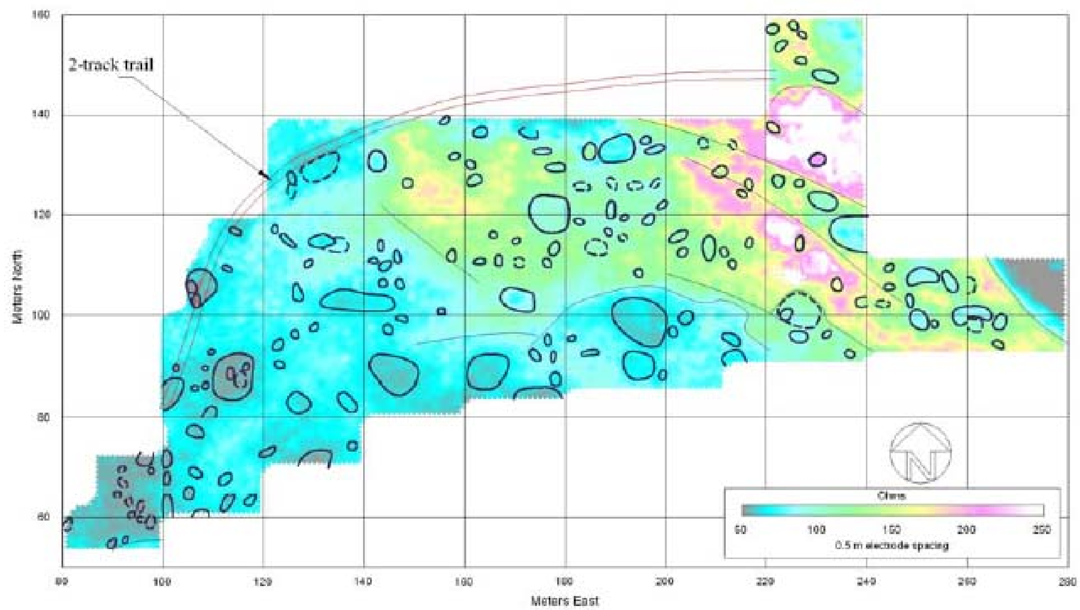


Magnetic gradient map from Silvernale site

plow furrows. These are visible across the entire survey area. A track near the northern limit of the survey area is also evident. Several high amplitude anomalies with limited extent are probably due to historic metal. More subtle anomalies not obviously associated with farming are interpreted to be of likely prehistoric origin.

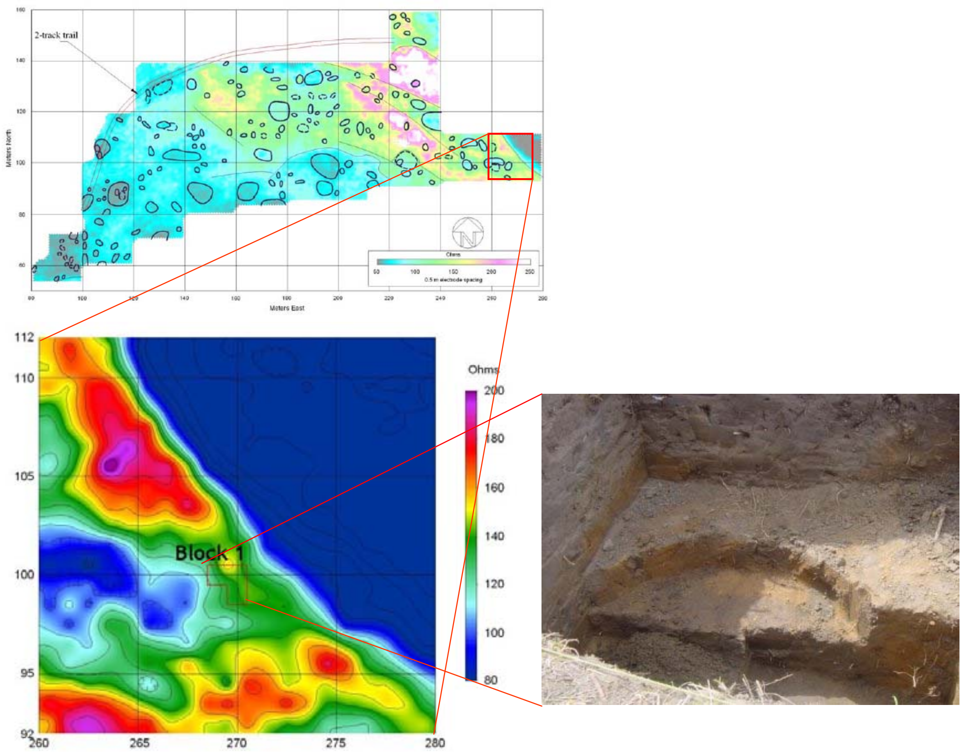
The resistance data were gathered with a Geoscan RM15 resistance system. Data were collected along north-south transects 1 meter apart in 20-meter grids. Measurements were taken at intervals of 0.5 meters using two different mobile electrode separations at each location: one-half meter and one-meter. Strong differences in the resistance values across the site are interpreted as being mostly due to natural causes (local soil stratigraphy). The areas of higher resistance values generally indicate sandier soil while lower resistance is indicative of soils with higher clay content. The resistance values are lowest in the southwest part of the survey area and highest in the northeast. An area of low resistance material in the far east of the site is recent fill that was spread over a portion of the Silvernale site, presumably during construction of the adjacent Industrial Park.

The resistance anomalies most likely to be due to cultural features are the isolated relative lows. Pits are typically filled with organic-rich material and are possibly less compact/higher moisture content than the surrounding soil. These conditions usually result in resistance lows. Numerous discrete resistance lows have been identified at Silvernale and are shown as interpreted features on a composite resistance map. Results from both electrode separations were reviewed and those lows that appear in both sets are probably the most likely to be archaeological features. Visual inspection of the interpreted features indicates they are present in two different sizes. The larger ones are average approximately 7 meters across, while the smaller ones are roughly 2 meters across. Resistance lows covering larger areas may represent house floors or large middens, whereas the smaller are interpreted to be pits.

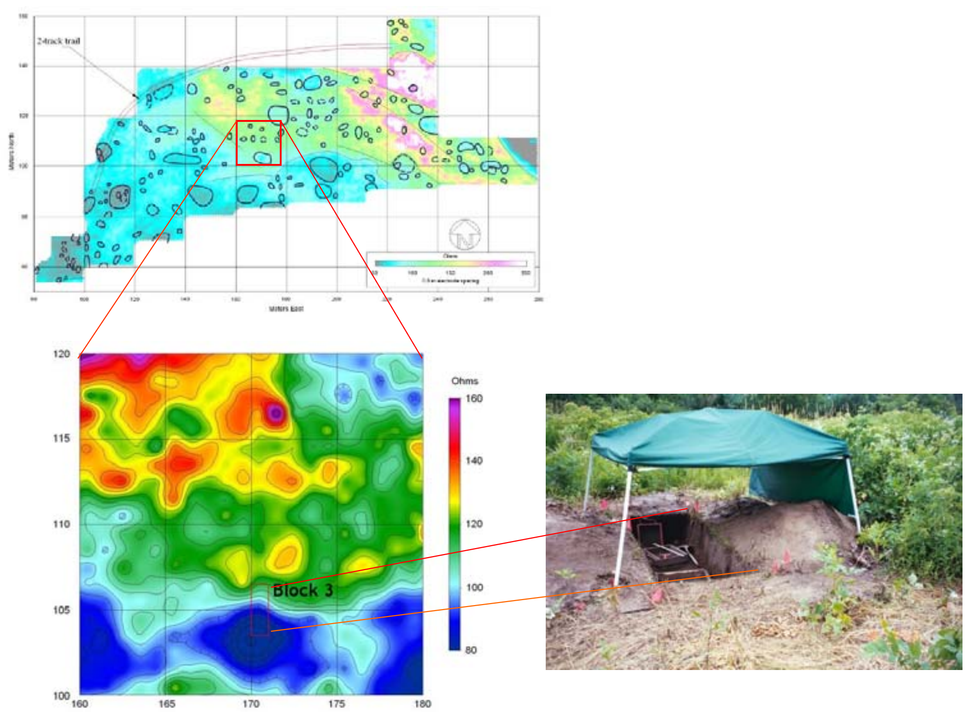


Interpretation of cultural features superimposed over soil resistance map from Silvernale site

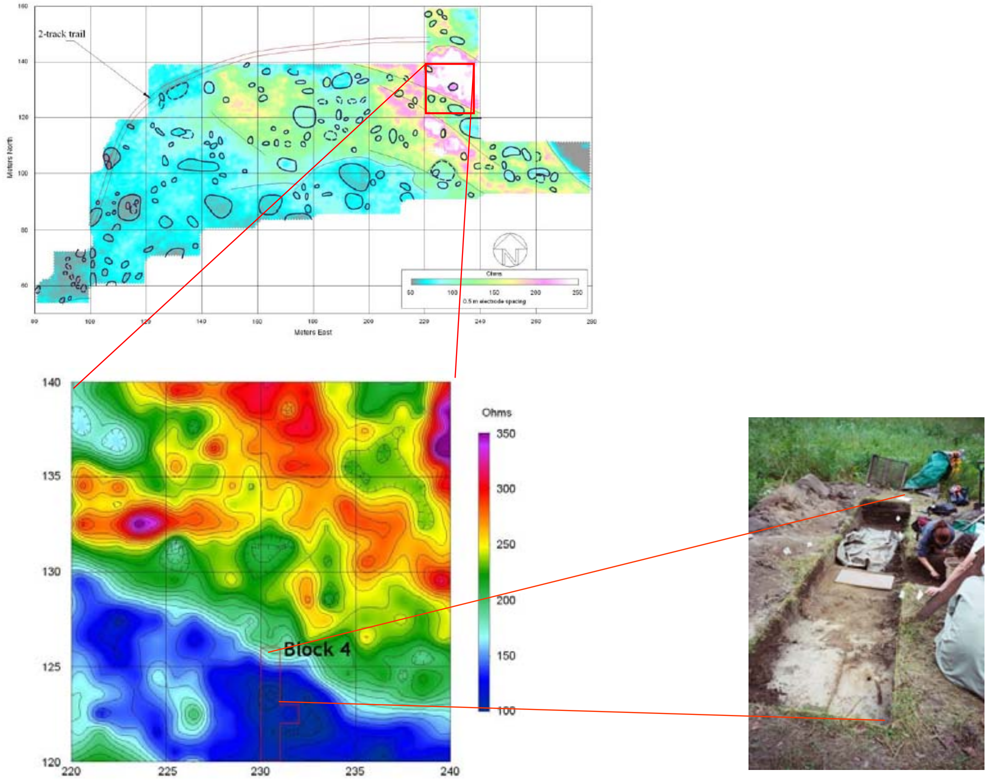
Unit excavations by students at Mankato State University from 2003-2005 have verified much of the geophysical interpretation, as shown in the following images.



Block 1 excavations – 15 to 20 cm of midden beneath plow zone with independent pit feature beneath



Block 3 excavations – house floor encountered at resistivity low



Block 4 excavations – Excavation revealed a surface midden immediately beneath the plow zone and about 15 to 20 cm thick, similar to the midden encountered at Block 1. Two features were encountered beneath the midden, a pit containing organic-rich material (resistance low) and a pit containing burned pottery and other burned material (weak resistance high).

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