NARRATIVE FINAL REPORT

Development of \textit{in situ} Shallow Subsurface Spectroscopy for the Geochemical Characterization of Archaeological Features and Anthropogenic Soils

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Executive Summary

NPS Grant P15AP00378 funded a proposal to investigate “the feasibility of employing shallow subsurface geochemical survey in archaeological prospection”. We proposed using existing technology at three archaeological sites in Kansas in order to “establish data collection protocols, the range of potential target chemical signatures, their archaeological correlates, and equipment detection limits under differing soil conditions”.

As detailed below the fieldwork in Kansas was completed using the resources provided by P15AP00378 and has generated an exceptionally large and rich dataset bearing on the proposed initial research plan. A robust system for collecting data across three-dimensional grids at archaeological sites was established and tested at the three field sites. Initial results include a determination of ideal sampling densities (sample and transect intervals), at least in the research region. Significantly, we have been able to improve upon the calibration protocols used when collecting spectra using the Veris P-4000 system through the creation of algorithms compensating for drift over time, perhaps related to diurnal and instrument temperature changes. Spectral and chemical signatures for certain features were determined through testing of known archaeological deposits at the Kansas Monument site, and were subsequently tested at unexcavated portions of the Tobias East and Tobias West sites. Considerable improvements over our earlier mapping of analytes, including 3D rendering of different variables is providing valuable information about the spatial covariation of different analytes as well as their correlation to known (and unknown) archaeological features. Continuing exploration of the spectral and chemical data from the project funded by P15AP00378 promises to aid on-going development of viable geochemical prospection equipment for use in archaeology.
Introduction

Background

This project focused on the development of new technologies to help archaeologists and heritage managers with cultural resource detection, documentation, and management. As noted in our grant proposal, this project built upon a previous pilot study by the PIs and research team adapting existing in situ geochemical soil testing equipment (Veris P-4000) initially developed for commercial agriculture to archaeological prospection (Matney, et al. 2014). Potential applications of this technology are wide-ranging, including archaeological, Native American and historic preservation, historical landscape, and forensic applications. This novel technology uses a mobile push-probe delivery system attached to a visible/near-Infrared (VIS-NIR) spectrometer to collect in situ spectra and other measurements which allows for the characterization of archaeological deposits (and other soils) in real time with minimal intrusion and damage to the underlying features. This is a significant innovation over lab-based soil tests which have a long, but limited, history of use in archaeology. In particular, this proposal requested funds for data collection at three sites in Kansas across a variety of archaeological features and soil types using a range of data collection protocols. These spectral and other data are used empirically to establish the range of potential target chemical signatures and their archaeological correlates, to determine equipment detection limits with the immediate goal of extending the technique to a broader range of archaeological features, and to establish best practices and recommendations for future improvements to geochemical prospection equipment currently available.

Sampling was conducted at three sites, although it must be noted that there was a last minute modification to the choice of sites. Originally, we had proposed work at the Kansas
Monument site (14RP1), the Tobias site (14RC8), and the Sharp’s Creek site (14MP301). The first two sites were part of this study; the latter site was unavailable for study during the window of fieldwork (it is privately owned and the owner was not present when we arrived), so we substituted another site for Sharp’s Creek. The third site is located immediately west of the Tobias site, although the cultural relationship between the two is not clear; in this report they are referred to as Tobias East and Tobias West. The latter has not yet been given a separate SHPO number [Fig. 1].

The Kansas Monument site (14RP1) near Republic, Kansas, comprises more than 40 Pawnee earth lodges built and used between ca. 1770 and 1830 (Adair, et al. 2007). In the spring of 2016 we surveyed an unexcavated area on the southern half of the site where a potential large storage pit is located in a plaza between several earth lodges seen in geophysical surveys [Area A]. In addition, we investigated a lodge where the hearth has been identified but the lodge perimeter has been difficult to detect through excavation [Area B]. In our previous study, lodge perimeters presented clear spectral signatures and this project will test the value of spectroscopy in detecting some properties of soil chemistry characteristic of archaeological features that are otherwise “hidden” to excavation.

The Tobias East Site (14RC08) in Rice County was occupied between AD 1500 and 1700 by the Wichita (Wedel 1959). The site is well known in the archaeological literature and is one of eight village sites that form part of the Tobias-Thompson Complex or Little River Archaeological District. These villages are on the National Register of Historic Places and are designated as National Historic Landmarks. Located on the Little Arkansas River, the Tobias site is notable for its “council circle”, a concentric earthwork about 60m in diameter whose function is unknown although ceremonial or fortification uses have been suggested. Within the council circle,
previous excavations had revealed a storage pit, mounded features including a possible house platform. Other known elements at the site, surrounding the exterior of the council circle, are houses or storage pits. The Tobias East Site is particularly important since human remains were found here during excavations in the 1940s, and it has been suggested that these represent burials or war trophies (Wedel 1959). Our survey was conducted over an area north of the council circle [Area C], outside of the excavated area, where a geophysical anomaly was detected.

The Tobias West Site has undergone very limited investigation. The land is owned by an amateur archaeologist, Chris Kurtz, who has made an extensive pedestrian survey of the Tobias West Site and surrounding fields, accumulating an inventory of nearly 1,700 artifacts. An almost imperceptible rise in topography – referred to locally as a possible “platform mound” – was investigated by our team [Area D]. Surface finds suggested initially that the Tobias West Site may represent an earlier component to the Tobias East site, although this interpretation is preliminary and only reflects a general reading of the surface remains.

Chronology of Fieldwork

Fieldwork took place in the spring of 2016 during the week of March 21 - March 25, 2016. Field sites were selected in consultation with Dave Maki, Robert Hoard (Kansas State Historic Preservation Office), and Chris Kurtz. As noted in our interim report, fieldwork was initially scheduled to take place in mid-October of 2015 in Kansas but was subsequently delayed until March 2016 due to logistical constraints. As detailed below, data collection at the three Kansas sites resulted in visible and near infrared spectra on 3-dimensional grids of points, together with insertion force and soil conductivity at each point. In the horizontal plane, the grids were a few meters on each side (4, 5, 10 m), and extended from the surface to a depth of
about one meter at each point in the horizontal grid. At the Kansas Monument site and at Tobias East, the grids were centered on the locations where the resistivity and magnetic gradiometry maps indicated anomalies. The Tobias West grid was an expanded sparser grid (20 m x 20 m) that included several a topographic feature locally interpreted as a platform mound and several anomalies detected via geophysical survey.

**Kansas Monument site (14RP1)**

The Kansas Monument site was explored archaeologically in 1949 and in 1965-1968, and was first surveyed using geophysical techniques in the summer of 2007 by a team from Archaeo-Physics, LLC led by Dave Maki as part of a project for the Kansas State Historical Society (Maki 2007). During the 2007 study, most of the site was surveyed using magnetic field gradiometry [Fig. 2] and select portions were the further investigated using electrical resistance survey [Fig. 3]. Based on the data obtained in the 2007 geophysical survey, an excavation was conducted at one of the earthen lodges by a Kansas Archaeology Training Program field school in 2008 under the direction of Donna Roper (Adair, et al. 2007) and later by the Kansas Historical Society in 2013 under the direction of Robert Hoard (Hoard and Hord 2013).

During our 2016 study, Maki resurveyed an area of the site located in a plaza between earth lodges that contained several suspected storage pits (Fig. 3). An electronic total station was set on the site datum and oriented to the site grid. The total station was then used to shoot in a 10 x 10 m grid centered on four suspected storage pits in this plaza area. This grid was resurveyed using a twin-probe electrical resistance meter with a mobile probe spacing of 75 cm. Data were collected in the north-south direction within this grid at a sample density of 16 reading per square meter (0.25 m x 0.25 m). The grid was then surveyed again in the east-west direction at a sample density of 16 reading per square meter. The north-south and east-west
data were combined during post-processing by averaging the two data sets. This approach minimized directional anisotropy in the resulting electrical resistance image (Fig. 4). The 2016 electrical resistance data were next used to establish a 4 x 4 m grid centered on a prominent circular anomaly (Area A). This grid served as the horizontal control during collection of geochemical and spectra data in Area A.

At the Kansas Monument site, we geochemically surveyed two areas using the Veris P-4000 equipment. Data were collected from Area A over a 4 m by 4 m grid at a sample interval of 25 cm along transects spaced at 25 cm intervals (16 samples/m²). This survey grid was located over a well-defined electrical resistance anomaly [Fig. 4]. In Area A we probed 361 locations and collected 11 soil cores. Each probe location has roughly 24 associated spectra and each spectrum represents about 385 data points. Thus, we collected 3.34 million data points in Area A. Likewise, each core is divided into 10cm segments, providing us with 108 soil subsamples for chemical and further spectral analysis in the lab. The cores represent our training set. This work was done on March 21.

Area B consisted of two perpendicular transects which intersected near the center of an earthen lodge [Fig. 5]. As noted above, previous excavation by Hoard in 2013 had located a central hearth which was believed to be in a lodge (House 26) that did not burn down and, hence, was difficult to confirm archaeologically (Hoard and Hord 2013). Our east-west transect was 22.5 m long and had a variable sample interval. Those areas corresponding to the expected house edges were sampled at 0.25 m sample intervals while the remainder of this transect was sampled at 0.50m sample intervals. The transect extended outside of the expected house edge. The north-south transect was 14.0m long and also had a variable sample interval. The section of the transect that intersected the hearth was sampled at 0.25 m sample intervals, while the
remainder of the transect was sampled at 0.50 m intervals. In total, 133 probe locations and 7 soil cores were collected providing 1.23 million data points and 61 soil samples. This work was done on March 22.

**Tobias site (14RC8)**

As noted above, the Tobias site near Geneseo, KS has two components: an eastern portion that has been well-studied by archaeologists (i.e., the council circle area) and a western section which is currently privately owned and has not been excavated. The presence of a possible archaeological site at Tobias West was suggested by surface materials recovered by the landowner and by a LiDAR data analysis completed by Maki prior to the 2015 National Park Service (NPS) archaeological prospection workshop, which was held at the Tobias site during May of that year.

As noted above, excavations at the council circle of the Tobias East site took place starting in the 1940s. During the 2015 NPS Workshop, magnetic field gradient, electrical conductivity, magnetic susceptibility, and ground penetrating radar data were collected by students and instructors over an 80m by 80m area centered on the council circle. A number of anomalies of interest were identified in the resulting data, both inside and outside the council circle. Several of these anomalies were tested during the NPS workshop using downhole magnetic susceptibility testing methods. One of these cores (Core 5) was centered on a circular positive magnetic field gradient anomaly with a diameter of approximately 2 m (Fig. 6). This magnetic anomaly is located 15 m north of the northern limit of the council circle. Downhole magnetic susceptibility testing data from Core 5 revealed a clear high-contrast increase in magnetic susceptibility values when compared to a nearby control core that was collected from an area devoid of magnetic anomalies (Fig. 7) which strongly suggested this anomaly was caused
by an archaeological feature. Based on this information the “Core 5” magnetic anomaly was targeted for geochemical spectra data collection during our 2016 study.

The UTM coordinates of the Core 5 anomaly were digitized from the 2015 NPS Workshop magnetic data and input into a handheld GPS unit as a waypoint. This waypoint was re-located in the field on the afternoon of 22 March, 2016 and a 20 x 20 m survey grid was established over the anomaly. This grid was subsequently re-surveyed using both magnetic field gradient (16 samples/m²) and electrical resistance (4 samples/m²) survey. The results of this 2016 survey were used to establish Area C, a 5 x 5 m grid centered over the Core 5 anomaly (Fig. 8, Fig. 9).

Geochemical data were collected over Area C using the Veris P-4000 probe system and spectrometer at a sample density of 0.5 m x 0.5 m (4 samples/m²). In Area C geochemical data collection included 121 probe locations and 9 soil cores collected providing 1.12 million data points and 74 soil samples.

At the Tobias West site, previous archaeological work comprised surface surveys conducted by the field owner, as noted above, and magnetic gradiometry and electromagnetic conductivity/susceptibility surveys over a 40 x 40 m area centered on a newly discovered platform mound (Fig. 10). The geophysical data were collected by instructors and students during the 2015 NPS Archaeological Prospection Workshop. In 2016, Maki surveyed a 60m by 40m area using electrical resistivity after re-establishing a survey grid over the platform mound. This survey utilized at 75 cm twin probe frame at a sample density of 4 samples/m². The LiDAR and geophysical maps generated by Maki served as the basis for the selection of geochemical data collection Area D (Fig. 11). Using the Veris P-4000, we collected data over the 20m by 20m grid at a sample interval of 1.0 m x 1.0 m (1 sample/m²). Area D is centered on a platform
mound, and numerous electrical resistance anomalies in and around the mound have signal characteristics that suggest storage pits or hearths are located within the survey grid (Fig. 11). Area D geochemical data collection included 441 probe locations and 10 soil cores providing 4.07 million data points and 101 soil samples. An initial N-S transect of data was collected on the evening of March 23 after completing work on Tobias East to test the nature of the site. Subsequently the grid was collected in full on the following two days, May 24-25.

Field Methods

Spectrographic survey

The basic field procedure for the spectrographic survey was similar to that used in our earlier project (Matney, et al. 2014: 318). As reported in that publication, in situ spectral data were collected using a Veris P4000 VIS-NIR-EC Force Probe. This instrument records spectral information in the range of 350 to 2,250 nm, with an 8 nm resolution using an Ocean Optics USB4000-VIS-NIR spectrometer (sensitive in the range of 350 to 1,050 nm) and a Hamamatsu Spectrometer C9914GB (sensitive in the range of 1,100 to 2,250 nm). The 2.5 cm diameter probe collects light through a 15 mm sapphire window and transmits it through a fiber optic cable to the spectrometers. Additionally, the probe contains instruments that measure electrical conductivity (in mS/m) and the required insertion force to a maximum of 7,000 kPa. The probe is inserted into the ground using a hydraulic system mounted in the back of a truck. Probe depth ranges from the surface to roughly 1.0m with an insertion speed of approximately 2 cm per second. Spectra are collected at a rate of 20 spectra per second, and averaged to provide spectral absorbance, electrical conductivity, and insertion force information at roughly 5 cm depth intervals. The instrument was initially calibrated against known reflectance standards.
before data is collected. Every 15 minutes the instrument is then checked with a dark and reference measurement to account for any drift in the light source or spectrometers due to temperature. Data processing issues arising from the calibration protocols are discussed in some detail below.

_Coring_

We also extracted soil core samples on a very limited subset of the grid points, including at a number of geophysical survey anomaly locations. The core samples were taken using a hydraulic rotating coring kit attached to the P-4000; soil was collected in polymer core sampling tubes with an outside diameter of 5cm. Depth was recorded using an electronic stringpot. Each soil core was subsequently divided into vertical segments of 10cm for chemical analysis.

_Analytical Methods_

The basis of the Veris instrument, and of our chemometric analysis of the spectral data, is the idea that the spectra contain implicitly within them much of the information yielded by the chemical analysis. We employ a principal component analysis (PCA) and regression (PCR) to model the spectra accordingly. The result is that we obtain approximate concentrations of several analytes on each of the full three-dimensional grids.

_Chemometric analysis_

Chemometrics is central to all of the work that has been done. Imagine two sets of data, one set comprised of spectral measurements fashioned in a three-dimensional grid and the other set comprised of more specific chemical measurements at select vertical shafts in the grid.
The chemical analyses gave determinations of the analytes: organic matter, potassium, phosphorus, calcium, sodium, magnesium, and soil acidity (pH). Thus, select locations in the grid would have both spectral data and chemical data. It is the goal of the chemometric analysis to find connections between those two data sets (spectral and chemical) that can be used to build a reasonably acceptable model which is then applied to the rest of the grid.

**Principal Components Analysis (PCA)**

The first step in this process is principal component analysis (PCA). During this step, only the spectral data is analyzed in order to suggest a number of principal components that may be present in the sample. One can think of these components as if they are variables in the function that fully describes the sample. Once the number of principal components is established, the next step is principal component regression (PCR). This process generates a calibration matrix that, when applied to spectral data, can estimate the chemical data at each location. This is done by linking the spectral data to the known chemical data at the same locations in the grid.

**Validation**

In order to test the validity of the models, each of the data sets was split into two sections: a training set and a validation set. The training set comprised roughly 80% of the spectral data from locations with known chemical data obtained through coring and chemical analysis; the remaining 20%, the validation set, is used to judge the effectiveness of the model. Because one knows the chemical data for that 20% of spectral data, once a model is generated it is applied to the spectral data. Thus, the end product is a prediction of the chemical data which can be directly compared to the actual chemical data.
Correlation coefficients between the measured and predicted analyte concentrations for the validation set were used to determine the reliability of the model predictions. A correlation coefficient above 0.8 was obtained for several analytes, and although not fully quantitative, these determinations were considered useful for the purposes of mapping the analyte concentrations on the three-dimensional grids. Horizontal slices through the mapped data show non-random anomalies in the analyte concentrations, which we might attribute to ancient human activity. An example is seen in Fig. 12.

**Calibration**

Our preliminary examination of the absorbance data suggested that, in a few cases, the periodic calibration of the spectrometer that was performed in the field may have had an anomalous influence on the final absorbance readings. In particular, one calibration set for 12 probe locations from Area A at the Kansas Monument site had absorbance that was anomalously light in comparison to its neighbors [Fig. 13]. Considering that there may be some fault in the calibrations developed by Veris Technologies, we chose to redesign the calibration effort. It must be pointed out that this field equipment is designed to be used in agricultural fields on a very, very low sample density (on the order of a few samples per hectare) and looking at only a limited range of analytes; the calibration effort used by Veris is appropriate to this goal, but not necessarily for a high sample density survey of archaeological deposits.

As noted above, in the field, two calibration measurements were taken approximately every 15 minutes and applied to the measurements that follow until the next calibration is taken. Ideally, these measurements would remain static, but unfortunately there are many variables that could influence them. Uncontrollable external factors such as the temperature of the environment or internal factors such as the temperature of the probing equipment could
sway these calibrations. Thus, the calibration measurements are re-taken over the course of the data collection. One measurement, the dark calibration, did not vary much from reading to reading, though a slight increasing trend with time of day was observed. The reference calibration, however, varied more and did not show a regular trend with time. The reference calibration measurements in at least two cases were significantly lower than others, suggesting that there had been some error in at least these readings.

We therefore attempted two methods of correcting for the effects of the problematic calibrations: (1) a modeled trend was calculated for each wavelength and each day in the field for both the dark and reference calibrations; and (2) a modeled trend was calculated for the dark calibration for each wavelength and field day, but for the reference calibration the average of all values was applied over both days. Both methods appeared to eliminate the problem with the anomalous absorbance values in the data from the Kansas Monument site.

For the Kansas Monument site, 49 separate calibration measurement sets (a set = one light, one dark) were collected. Because these measurements vary with calibration number, the current research goal is constructing an algorithm that applies a separate fit to each of the 400 measured wavelengths. These fits could then be used to devise root mean square deviations (RMSD) for the calibration measurements, which indicate the presence of outliers in the data set. By removing outliers and refitting the calibration points, one achieves a more accurate calibration for the spectral absorbance values used to produce the chemical model.

As of this report, we have made very significant progress and the algorithm is well advanced in its development. It is being designed such that it could be applied to any future data set. This would guarantee that data sets collected by the Veris instrument could always be processed efficiently manner. For the Kansas Monument site, once the algorithm is complete
and applied to the data, principal component analysis and regression will be performed again. This will generate a new set of correlation coefficients to be compared to the set produced using the old calibration. In addition to the algorithm described above, we are also automating similar processes such as depth interpolation. The need to develop the calibration correction algorithm has delayed the final analysis of the data, but is essential to the long-term utility of this technology. We anticipate production of a draft peer-reviewed publication by the end of the calendar year.

Results and Discussion

Kansas Monument site

In the case of the Kansas Monument site, the full spectral data covered measurements from 400 to 2400 nm at 289 probe locations up to 1m in depth. Geometrically this describes a 17 by 17 grid of probe locations over a 4 m by 4 m square in Area A, with a sample interval of 25 cm. This data can be visually represented as contour plots at a constant depth. In that way, one can see how one variable changes with the northing to easting at one depth measurement throughout the site. Similar plots could be created for each variable that was found to have a sufficient correlation coefficient. Likewise, plots of constant easting and varying northing and depth could be created as well, illustrating a vertical slice of the grid as opposed to the horizontal slice seen above.

Tobias East and West sites

As with the Kansas Monument site, in order to perform the chemometrics analysis and obtain the estimates of analytes at the Tobias East and West sites, the core and spectral data
was divided into two sections: a training set and a validation set. In addition to an analysis of each site individually, we also combined data sets from both Tobias sites together for chemometric analysis. This is allowable as the sites are within close geographical proximity (<1km) and they are both located in pedologically-similar regions (Fig. 10). Principal Component Analysis (PCA) was done on these three data sets (Tobias East, Tobias West, and Combined) [Fig. 14]. Correlation coefficients for the Tobias East site and the Tobias West site were determined by applying the Tobias East site model on the Tobias East validation set of analyte concentrations and the Tobias West site model on the Tobias West validation set of analyte concentrations respectively. Principal Component numbers 53, 23 and 36 from the Tobias West site PCA were used to make these models. The Combined Tobias dataset model was also applied on the Tobias East-only data set, the Tobias West-only data set and the Combined sites data set. These correlation coefficient values indicate that the Combined sites model applied on Tobias East-only and Tobias West-only datasets results in the best predicted values of the analytes. The model works using the Principal Componenet Regression (PCR) method to produce the estimated concentrations for the respective components. From Fig. 15 it can be seen that the correlation coefficient of Tobias East site data model applied on Tobias East site data is slightly lower (0.64) than the Combined sites data model applied on Tobias East site data (0.66). Thus, the Combined sites model was applied on both Tobias East and Tobias West only data. The obtained concentration values were compiled with respective depths, northing and easting values of the site for further plotting and comparison.

As with the Kansas Monument site, the horizontal slices of various depths were plotted for both Tobias sites. In the contour plots, the analytes were plotted with respect to corresponding easting and northing positions of the site. The contour plot color is assigned as the rainbow pattern where the lower values are red and the higher values are blue. The color
consistency was retained by setting the range of each analyte from the lowest to highest concentration. Contour plots of Organic Matter (OM), pH, calcium, magnesium, CEC, probe insertion force, potassium and sodium was obtained representing the concentration variation at different depths. In Fig. 16 the contour plots of OM and pH at depths of 77.5 cm, 82.5 cm and 87.5 cm at the Tobias East site are shown. At Tobias East, a central high OM concentration pattern is observed starting from 67.5 cm and continues down to the lowest depth measured. This central pattern is also supported by potassium, probe insertion force, CEC and magnesium. A smaller high OM pattern is also observed at the upper right corner of the plots from the same depth, supported similarly by other analytes. In Fig. 17 the OM concentration in Tobias East site at a depth 87.5 cm is shown with the range of concentration for this horizontal slice only. This indicates the contrast of different concentration values represented in the contour plot.

Conclusions

Working at the Kansas Monument site, where the archaeological contexts were already well established, the use of the shallow subsurface spectographic prospection technique was demonstrated to work well. Clear indicators of buried archaeological features are seen in the spectral data. The sample density used there (16 samples/m²) provides high resolution data. Modeling of features at the Tobias West and Tobias East sites is still on-going, although clearly non-random patterning is evident even from our preliminary mapping. The moderate resolution data collected as Tobias West (4 samples/m²) provides enough resolution to characterize the features previously identified via geophysical survey. Finally, the low resolution data collected at Tobias East (1 sample/m²) appears to be insufficient to resolve features of archaeological interest via spectroscopy. In particular, our initial chemometric analysis does not result in
smooth contours of analyte concentrations because there is considerable variation across the
distances between probes (1.0m vertically and horizontally, 1.4m diagonally).

To our knowledge, these efforts at three-dimensional mapping of the chemical content
of the soil at different depths using spectroscopy is without precedent in an archaeological
context. As combined here with geophysical survey methods, this approach represents the
dawning of a new era in our ability to characterize archaeological sites in advance of excavation.
This information might be used to judge the priority of a given location for excavation or, in
other cases, help determine whether the site should be preserved in its unexcavated state for
cultural resource management reasons.
Fig. 1. Location of the Kansas Monument site and Tobias site in central Kansas.
Fig. 2. Magnetic gradiometry data from 2007 at the Kansas Monument site. The 2016 electrical resistance survey grid is shown in red.
Fig. 3. Electrical resistance data from 2007 showing the circular Pawnee earth lodges in relation to the 10 x 10 m electrical resistance survey grid at the Kansas Monument site. This grid was re-surveyed using an electrical resistance meter during our 2016 study. Results of this re-survey are shown in Fig. 4.
Electrical resistance data collected in March of 2016 at the Kansas Monument site. The yellow box (Area A) encompasses a circular electrical resistance anomaly that was interpreted as a storage pit. A 4 x 4 m grid was established over Area A and used to control collection of our geochemical spectra.
Fig. 5. Location of Area B transects (in red) plotted on 2007 electrical resistance data from the Kansas Monument site. Note that the central hearth appears as a relative resistance low (lighter colored). The north-south geochemical spectra transect bisected this hearth.
Fig. 6. Tobias site magnetic field gradient data are overlaid on a LiDAR local relief model elevation image. Core 5 tested a 2 m diameter magnetic anomaly using downhole magnetic susceptibility methods. Core 6 represents a control core placed in an area devoid of magnetic anomalies.
Fig. 7. Downhole magnetic susceptibility testing results from the 2 m diameter magnetic anomaly highlighted in Fig. 6. Core 5 shows a clear increase in magnetic susceptibility values when compared to a nearby control core. These data were collected during the 2015 NPS archaeological prospection workshop.
Fig. 8. Results of the 2016 magnetic field gradient re-survey over the Core 5 anomaly. A 5 x 5 m grid was established over this magnetic anomaly and used for horizontal control during geochemical spectra data collection (Area C).
Fig. 9. Results of the 2016 electrical resistance re-survey over the Core 5 anomaly.
Fig. 10. The locations of geochemical survey grids Area C and Area D are plotted on a LiDAR local relief model elevation image. Dark areas of the image represent local increases in elevation while white areas represent local decreases in elevation. The image greyscale is constrained to ± 25 cm.
Fig. 11. Area D electromagnetic conductivity data (top) and electrical resistance data (bottom). Note: the 2015 survey grid was no longer in place during our 2016 study. In 2016 the platform mound was re-located using a GPS waypoint and a new survey grid was established using triangulation with tape measures. An error in grid placement resulted in a slightly skewed grid. This error was corrected in the resulting data imagery while geo-referencing the electrical resistance image.
Figure 12. Kansas Monument site - Area A. The modeled organic matter content at depth 0.575 m. The color green represents relative high values while the color red represents relative low values. (b) The insertion force readings at depth 0.575 m. Note, this variable was not modeled using chemometrics, but rather directly measured while spectral measurements were being taken. The color green represents relative high values while the color red represents relative low values. These two graphs were chosen because they both point towards the presence of an archeological feature found in the center of Area A at increasing depths.
Figure 13. Kansas Monument site – Area A. This figure represents the average red absorbance over all wavelengths and depths at each probe location. One calibration set near the upper right center can be seen as having much lighter absorbances than all of the surrounding calibration sets.
<table>
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Fig. 14. Principal Component Analysis (PCA) of Tobias East, Tobias West and Combined Tobias Sites data set employing various methods.

Fig. 15 Correlation coefficient values for the Tobias data set.
Fig. 16. Contour plots of Organic Matter (OM) and pH at 77.5cm, 82.5cm, and 87.5 cm depths at the Tobias East site – Area C.
Figure 17. Contour plot of Organic matter at 87.5 cm depth with the respective range of OM at 87.5 cm depth only at Tobias East site – Area C.
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