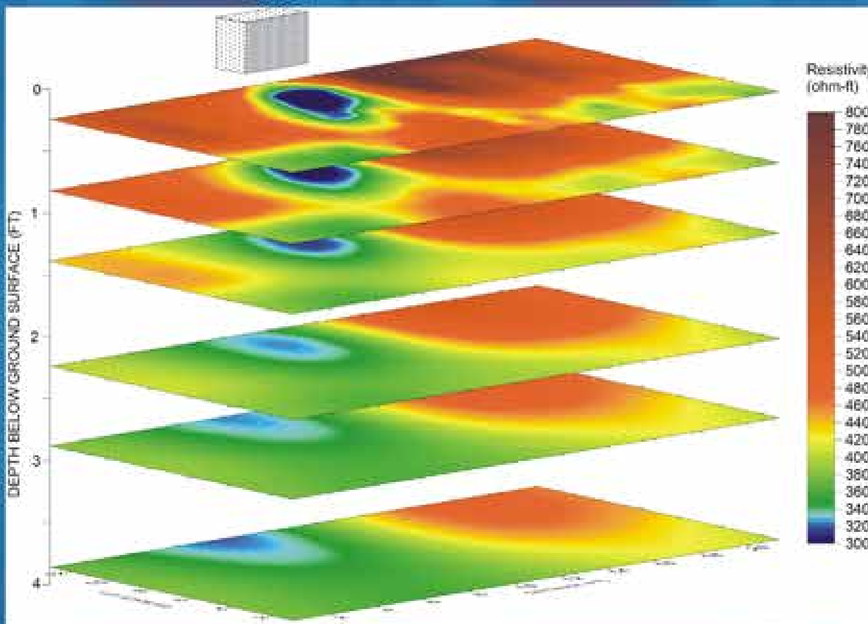
*Fast*TIMES

Archaeological Geophysics:



The Search for Subterranean Kofun Burial Chambers on the Island of Kyushu, Japan Using Ground Penetrating Radar

Looking for Lost Graves

Geophysical Investigations at the Cold Springs Station Site: A Pony Express Station in Lincoln County, Nebraska

Multi-Sensor Geophysical Examination of the Historic Distillery: Brenham, Texas

Merging Cultures and Curriculums: Enriching Heritage and Education with Applied Geophysics

The Archaeological Geophysics Program at the University of Kentucky

A Magnetometer Survey at the Confederate POW Camp Site of Camp Lawton in Jenkins County, Georgia

June 2015

Volume 20, Number 2

In this special issue of *Fast*TIMES, there are seven articles focused on the application of near-surface geophysics to archaeology.

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ISSN 1943-6505

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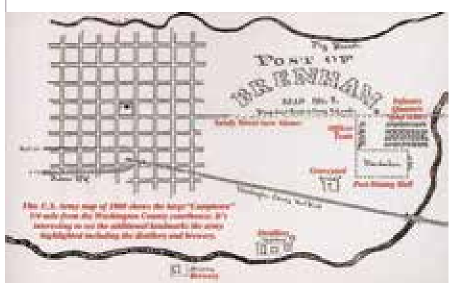

Articles

*Fast*TIMES

*Fast*TIMES (ISSN 1943-6505) is published by the Environmental and Engineering Geophysical Society (EEGS). It is available electronically (as a pdf document) from the EEGS website (www.eegs.org).

ABOUT EEGS

The Environmental and Engineering Geophysical Society (EEGS) is an applied scientific organization founded in 1992. Our mission:

"To promote the science of geophysics especially as it is applied to environmental and engineering problems; to foster common scientific interests of geophysicists and their colleagues in other related sciences and engineering; to maintain a high professional standing among its members; and to promote fellowship and cooperation among persons interested in the science."

We strive to accomplish our mission in many ways, including (1) holding the annual Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP); (2) publishing the Journal of Environmental & Engineering Geophysics (JEEG), a peer-reviewed journal devoted to near-surface geophysics; (3) publishing *Fast*TIMES, a magazine for the near-surface community, and (4) maintaining relationships with other professional societies relevant to near-surface geophysics.

JOINING EEGS

EEGS welcomes membership applications from individuals (including students) and businesses. Annual dues are $90 for an individual membership, $50 for introductory membership, $50 for a retired member, $50 developing world membership, complimentary corporate sponsored student membership - if available, and $300 to $4000 for various levels of corporate membership. All membership categories include free on-line access to JEEG. The membership application is available at the back of this issue, or online at www.eegs.org.

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*Fast*TIMES is published electronically four times a year. Please send articles to any member of the editorial team by Sept. 1, 2015. Advertisements are due to Jackie Jacoby by Sept. 1, 2015.

CALENDAR

2015

August 25 - 27	Potential-Field and Electromagnetic Methods Applied to Basin Studies: American Geophysical Union and Society of Exploration Geophysicists Workshop Keystone, Colorado, USA http://workshops.agu.org/seg/
August 27 - 28	Multichannel Analysis of Surface Wave (MASW) Workshop Lawrence, Kansas, USA http://www.kgs.ku.edu/software/surfseis/workshops.html
September 6 - 10	Near Surface Geoscience 2015 Turin, Italy http://www.eage.org/event/index.php?eventid=1119&Opendivs=s3
October 5 - 9	14th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst Rochester, Minnesota, USA http://www.sinkholeconference.com/
October 26 - 31	Society of Exploration Geophysicists International Exposition and 85th Annual Meeting New Orleans, Louisiana USA http://www.seg.org
November 15 - 18	3rd International Conference on Engineering Geophysics Al Ain, United Arab Emirates http://www.seg.org/events/upcoming-seg-meetings/2015/iceg-uae-15
November 24 - 26	3rd International Conference on Geoelectric Monitoring (GELMON 2015) Vienna, Austria http://www.geophysik.at/index.php/workshop-gelmon-2015

2016

March 20 - 24	Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) Denver, Colorado, USA http://www.eegs.org/sageep-2016 (Note: See page 91 for additional information.)

Please send event listings, corrections or omitted events to any member of the *Fast*TIMES editorial team.

NOTES FROM EEGS

PRESIDENT'S MESSAGE

Lee Slater, President

(lslater@rutgers.edu)

Shedding Old Skin

I am fortunate to write my first President's message during a time when EEGS is clearly on the rebound following a challenging year. There is no clearer indication of our organization's revival than the remarkably successful 2015 SAGEEP meeting held in Austin. EEGS owes great thanks to Jeff Paine (General Chair), Brad Carr (Technical Chair), sponsors, supporters, and the team of local organizers for putting together such a strong meeting. The total attendee count for SAGEEP 2015 makes it the largest SAGEEP meeting in the last decade. The community interest in SAGEEP 2015 provided a wonderful morale boost to EEGS, and I thank all those who participated in this historic and important near surface meeting.

As we look to the future, I am excited to advance four party talks on a truly joint near surface geophysics meeting that is being tentatively planned for 2017. There is now a real opportunity to join forces with American Geophysical Union (AGU), European Association of Geoscientists & Engineers (EAGE) and Society of Exploration Geophysicists (SEG) to convene a four party meeting where each organization plays an equal role in defining the technical content of the meeting. All three partner organizations have expressed a desire to collaborate with EEGS in this meeting under terms that the EEGS Board has determined will protect our organization whilst advancing the broader near surface community. I thank those involved in the partner organizations for their support and look forward to the fruits of our joint labor.

Other striking evidence for the revitalization of our organization is all around us. I was excited to sign a new memorandum of understanding (MOU) with AGU that will catalyze intersociety activities. Past President, Moe Momayez, recently signed similar agreements with EAGE, SEG and the SEG's Geoscientists Without Borders®. Membership is once again on the rise and we have new members joining and volunteering to serve on committees (EEGS always welcomes volunteers to help with the Society's business!). We have energized new board members committed to protecting and growing our society. We have an absolutely ravishing new look for our website, complete with sparkling advertising opportunities and functionality to support community networking activities.

It may seem a little odd to associate EEGS with a serpent, but it does feel very much like the organization has shed some dead skin to emerge revitalized for a new chapter in its history. One might envisage the failed merger negotiations with SEG like the snakeskin shed and crumpling under the desert sun: the beast has clearly moved on.

Lee Slater, EEGS President

EEGS Foundation makes great strides in its first years.

Since the launch of the EEGS Foundation, there are numerous accomplishments for which we can all be proud: Establishing and organizing a structure that serves the needs of EEGS; underwriting the legal process, achieving tax-exempt status; and soliciting and receiving support for SAGEEP. In addition, the Foundation helped underwrite the SAGEEP conference held this spring in Keystone.

These are only a few of the tangible results your donations to the Foundation have enabled. We would therefore like to recognize and gratefully thank the following individuals and companies for their generous contributions:

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NOTES FROM EEGS

Renew your EEGS Membership for 2015

Be sure to renew your EEGS membership for 2015! In addition to the more tangible member benefits (including the option of receiving a print or electronic subscription to JEEG, *Fast*TIMES delivered to your email box quarterly, discounts on EEGS publications and SAGEEP registration, and benefits from associated societies), your dues help support EEGS's major initiatives such as producing our annual meeting (SAGEEP), publishing JEEG, making our publications available electronically, expanding the awareness of near-surface geophysics outside our discipline, and enhancing our web site to enable desired capabilities such as membership services, publication ordering, and search and delivery of SAGEEP papers. You will also have the opportunity to donate to the EEGS Foundation during the renewal process. Members can renew by mail, fax, or online at www.eegs.org.

Sponsorship Opportunities

There are always sponsorship opportunities available for government agencies, corporations, and individuals who wish to help support EEGS's activities. Specific opportunities include development and maintenance of an online system for accessing SAGEEP papers from the EEGS web site and support for our next SAGEEP. Make this the year your company gets involved! Contact Lee Slater (lslater@rutgers.edu) for more information.

From the *Fast*TIMES Editorial Team

*Fast*TIMES is distributed as an electronic document (pdf) to all EEGS members, sent by web link to several related professional societies, and is available to all for downloading from the EEGS *Fast*TIMES web site (http://www.eegs.org/fasttimes). Past issues of *Fast*TIMES continually rank among the top downloads from the EEGS web site. Your articles, advertisements, and announcements receive a wide audience, both within and outside the geophysics community.

To keep the content of *Fast*TIMES fresh, the editorial team strongly encourages submissions from researchers, instrument makers, software designers, practitioners, researchers, and consumers of geophysics—in short, everyone with an interest in near-surface geophysics, whether you are an EEGS member or not. We welcome short research articles or descriptions of geophysical successes and challenges, summaries of recent conferences, notices of upcoming events, descriptions of new hardware or software developments, professional opportunities, problems needing solutions, and advertisements for hardware, software, or staff positions.

The *Fast*TIMES presence on the EEGS web site has been redesigned. At http://www.eegs.org/fasttimes you'll now find calls for articles, author guidelines, current and past issues, and advertising information.

Sincere thanks are extended to Daniel Bigman, who served as the Guest Editor for the 2015 June *Fast*TIMES. This special Archaeological Geophysics issue of *Fast*TIMES is one of our best yet, due largely to Dan's substantial efforts.

Submissions

The *Fast*TIMES editorial team welcomes contributions of any subject touching upon geophysics. *Fast*TIMES also accepts photographs and brief non-commercial descriptions of new instruments with possible environmental or engineering applications, news from geophysical or earth-science societies, conference notices, and brief reports from recent conferences. Please submit your items to a member of the *Fast*TIMES editorial team by Sept. 1, 2015 to ensure inclusion in the next issue. We look forward to seeing your work in our pages. Note: *Fast*TIMES continues to look for Guest Editors who are interested in organizing a *Fast*TIMES issue around a special topic within the Guest Editor's area of expertise. For more information, please contact Barry Allred (Barry.Allred@ars.usda.gov), if you would like to serve as a *Fast*TIMES Guest Editor.

JEEG NEWS AND INFO

The Journal of Environmental & Engineering Geophysics (JEEG), published four times each year, is the EEGS peer-reviewed and Science Citation Index (SCI®)-listed journal dedicated to near-surface geophysics. It is available in print by subscription, and is one of a select group of journals available through GeoScienceWorld (www.geoscienceworld.org). JEEG is one of the major benefits of an EEGS membership. Information regarding preparing and submitting JEEG articles is available at http://jeeg.allentrack.net.


The Environmental and Engineering Geophysical Society

Journal of Environmental & Engineering Geophysics

June 2015 Volume 20 Issue 2

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The Journal of Environmental and Engineering Geophysics (JEEG) is the flagship publication of the Environmental and Engineering Geophysical Society (EEGS). All topics related to geophysics are viable candidates for publication in JEEG, although its primary emphasis is on the theory and application of geophysical techniques for environmental, engineering, and mining applications. There is no page limit, and no page charges for the first ten journal pages of an article. The review process is relatively quick; articles are often published within a year of submission. Articles published in JEEG are available electronically through GeoScienceWorld and the SEG's Digital Library in the EEGS Research Collection. Manuscripts can be submitted online at http://www.eegs.org/jeeg.

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SUCCESS WITH GEOPHYSICS

*Fast*TIMES welcomes short articles on applications of geophysics to the near surface in many disciplines, including engineering and environmental problems, geology, hydrology, agriculture, archaeology, and astronomy. In this special issue of *Fast*TIMES, there are seven articles focused on the application of near-surface geophysics to archaeology. Special thanks to Daniel Bigman, who served as Guest Editor for this issue of *Fast*TIMES.

THE SEARCH FOR SUBTERRANEAN KOFUN BURIAL CHAMBERS ON THE ISLAND OF KYUSHU, JAPAN USING GROUND PENETRATING RADAR

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Introduction

Around seventeen hundred years ago, in the southern regions on the island of Kyushu, funerary customs began to take hold. Large earthen burial mounds of varying shapes and sizes began to appear on an elevated plateau surrounded by gradual valleys and nearby flatlands that were bounded by tall mountains (Figure 1). In what is called Miyazaki prefecture today, the burial rituals practiced by ancient farming communities, which included in some cases carving out secondary subterranean burial chambers beneath large mounded tombs, lasted till about the middle of the 7th century AD and had produced hundreds of earthen mounds that survive today. Several large mounded tombs constructed in Saitobaru, the Osaho and Mesaho Kofun burial

Keywords: Japanese Kofun Burial Chambers, Ground Penetrating Radar (GPR), Subsurface Remote Sensing.

mounds, are the largest earthen works in all of Kyushu, and because of their size were conscripted by the Japanese Imperial Family archaeologists in the late 1890s and designated to be sacred grounds that belong to the Kunaicho – Imperial Family. Folklore states that the Osaho and Mesaho mounds which are several hundred meters long and several tens of meters tall entomb the great grandparents of the first emperor of Japan in the 7th century AD

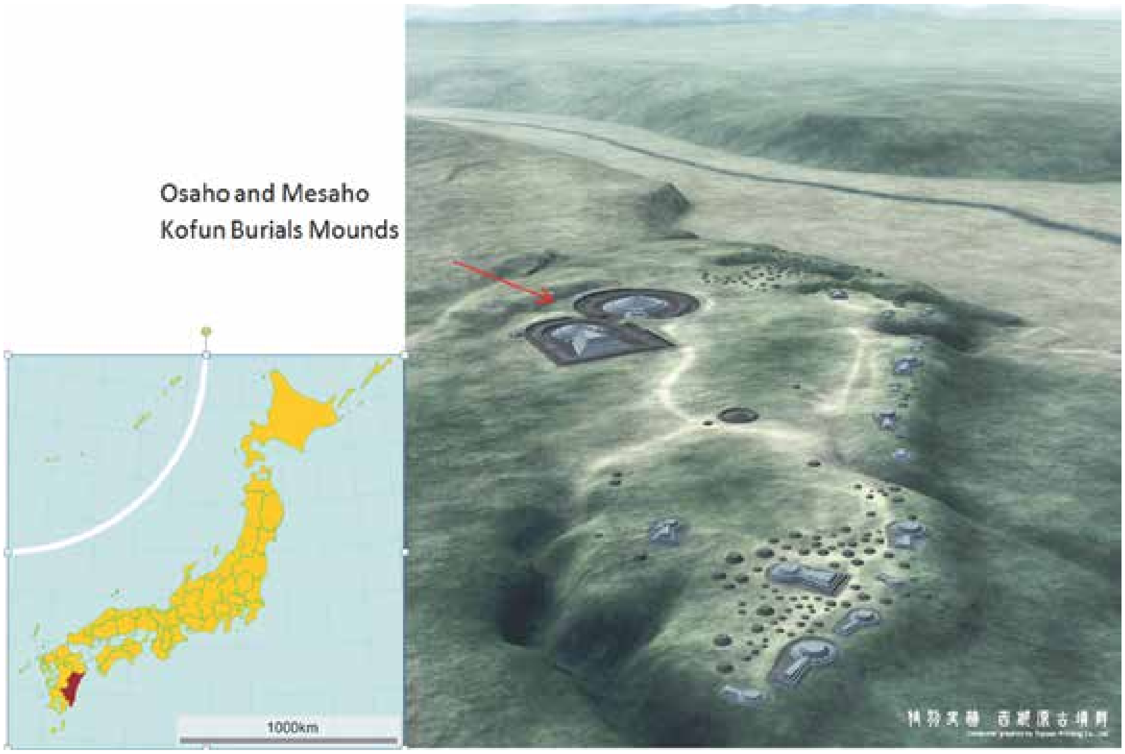

Figure 1: Map of Miyazaki Prefecture located on the southern island of Kyushu and a rendering of the Saitobaru National Burial Mounds [1]. The 2 largest mounds shown are the Osaho and Mesaho keyhole shaped burials which belong to the Japanese Imperial Family. The smaller mounds are administered by Miyazaki Prefecture.

Located about 50 km from the bustling city of Miyazaki, the Saitobaru tombs are unique in Japan in that such a high concentration of burial mounds that total over 350 could be found in one location, and more importantly, that so many of these ancient structures could survive the pressures from agrarian development over so many centuries. Though many of the burial mounds have survived, many have also been destroyed by ancient as well as modern farming activities up until the early 1900s. The level of destruction of some mounds is complete and no knowledge of their existence might ever be recovered. The shallow elevation on some mounds along with weathering disguised the existence that a burial once existed and the area might then have been altered for farming production. In the same sense, some burials survived because they were not known to be burials and their topographic relief was mild and not in the path of development. Other mounds were built with shallow surface burials on the top of the mounds for the deceased who had consigned for the building of their own tombs. Some of the mounds however would also have secondary burials carved beneath them for relatives, spouses or children that passed away after the main inhabitant was laid to rest. Upwards of 3-4 intact subterranean chambers beneath a single mound can be found intact in some locations. Recognized as a Japanese National Treasure, the Saitobaru Kofun Burial Mounds have been studied for over two decades with ground penetrating radar (GPR) in hopes of documenting and discovering many of the subsurface archaeological features stored beneath the ground as well as to hunt for lost subsurface chambers that still exist.

GPR Survey

GPR surveys were first initiated at Saitobaru in 1993 and are still being conducted at present in 2015 in searching the large 54 hectare site. The primary objective for the surveys is to discover lost subterranean chamber burials as well as to detect the presence shallow burials on the tops of the earthen mounds. Some of the earlier surveying successes also included discovery of buried moats surrounding intact as well as destroyed mounds [2, 3]. One of the most important discoveries to date was made from GPR surveys on the destroyed triangular portion of the Osaho mound. The site was altered with larger removal of soils to make a long earthen wall during the Edo period for samurai developing their archery skills. Using specialized overlay analysis where images at varying depths are used to synthesized important reflections across a whole band of depth ranges, a single image showing the shape of the destroyed triangular bottom of the Osaho mound could be reconstructed [2].

GPR surveys employing varying frequencies from 200, 270 and 500 MHz have been conducted. For some of the larger mounds, ancillary information is desired such as stratigraphic information which the lower frequency antenna are well suited to. Penetration depths with GPR are quite good in the highly resistive volcanic soils at Saitobaru and upwards of 200 ns of penetration can be easily achieved with even 500 MHz antennae. Profiles for most sites were recorded at 50 cm intervals and at 25 cm on the tops of the burial mounds. Radargram signal processing included dewowing, bandpass filtering, Kirchoff migration and Hilbert transform. Filtered radargrams were spatially resampled to create averaged squared amplitudes in consecutive overlapped windows that were approximately 30 cm thick in depth and 0.25 m in length. With the data binned, they were then interpolated with gridding options using a simple inverse distance algorithm to create solid 2D depth slices [4] at 5 cm pixels. 3D volumes of GPR reflections were generated via interpolation of normalized 2D depth slices, where each map has independent colorization transforms applied. The interpolation of the normalized 2D images into 3D volumes effectively uses the automatic gaining in the images – rather than in the radargram preprocessing - to generate auto gained volumes versus depth.

One site surveyed in the western areas in Saitobaru called Sakamotonoue contained a series of tunnel burial chambers that were discovered with GPR and then later excavated (Figure 2). The radar profile shows strong reflections from the ceilings of two intact chambers located in close proximity to one another. The chamber ceilings appear around 2.5 m below the ground surface. Using the entire dataset, a generalized isosurface rendering of the 75% strongest reflectors in the normalized volume could be used to show the 3D orientation, size and extent of the burial chambers. Excavations inside the subterranean chambers revealed an intact human skeleton along with pottery, swords, bronze mirrors and golden earrings. On several survey grids adjacent to this one, additional burial chambers were discovered. Prior to excavation of the site, air samples as well as a camera were inserted into the void space of the chambers to record the constituents of the ancient air before the burial was sealed in the 6th century AD. To protect the excavated burials from the adverse effects of weathering and the elements, a superstructure with controlled ventilation and temperature was built over the site.

The soil structure that makes Saitobaru suitable to the construction of subterranean chambers is the high concentration of ash in the soil. Mt. Kirishima which is still an active volcano today had actually last erupted on January 29, 2011 and preceded the Tohoku earthquake precariously by less than 6 weeks. This volcano has deposited volcanic ash from continuous episodes of steady eruptions for tens of thousands of years at the site. The deeply layered ash is hard packed and is a perfect natural and strong material that can be easily carved into and at the same time is able to support the overburden weight of soil above any excavated chambers. The depth to the ceiling of the burial chambers can be just 1-2 several meters below the original ground surface and have sizes as large as a walk-in closet in today's modern houses. The shallower the chambers are, the more danger some of them can be to the public. Heavier farming equipment employed today in Japan occasionally fall into one of these ancient chambers that once existed below a destroyed burial mound causing injuries.

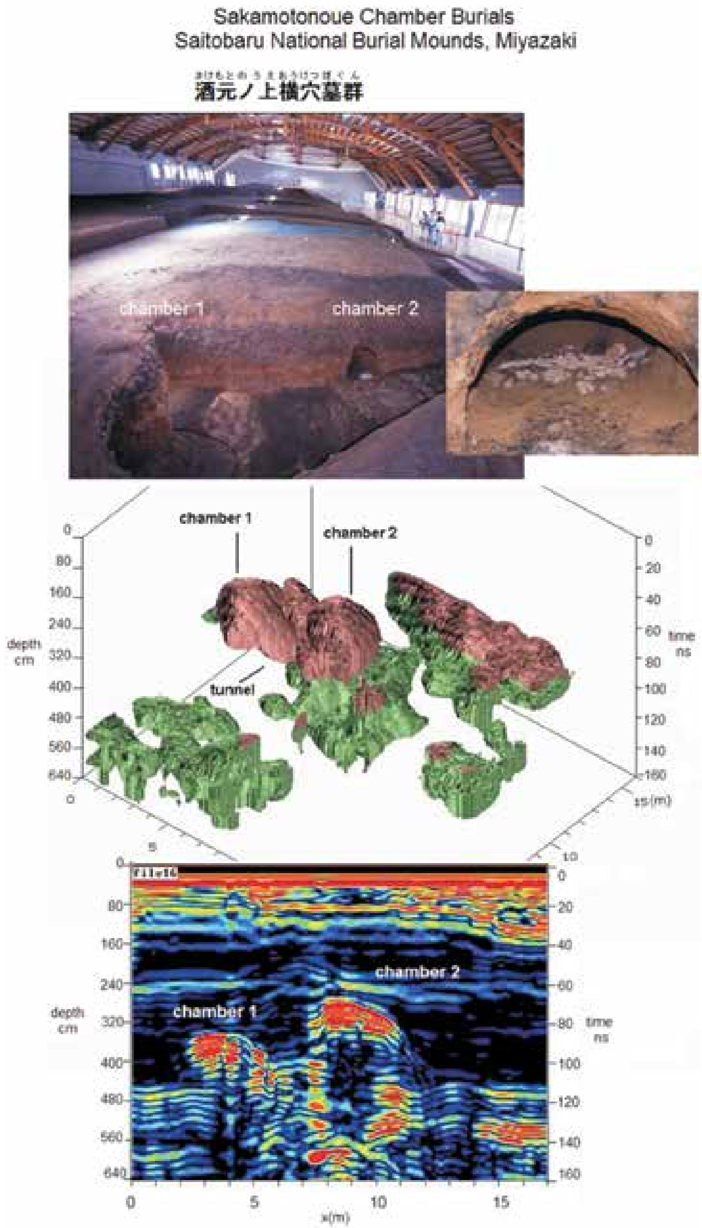

Figure 2: A radargram profile taken at the Sakamotonoue site shows two closely spaced subterranean chamber burial reflections. An isosurface rendering shows the general size, shape and depth of these chambers which were constructed in the Kofun period. A subsequent excavation photo shows the entrance to chamber burial #2 and the interior.

Shown in Figure 3 is a georeferenced depth slice from 1.1-1.4 m below the ground surface overlain on a Google Earth photo of an area in the southeastern portion of Saitobaru. This area is flanked by several keyhole shaped mounds that were partially excavated in the Taisho period over 100 years ago followed by more thorough excavations that were completed recently. Many satellite mounds of smaller sizes, 7-20 meters in diameter will often surround the larger burial mounds at Saitobaru. These smaller mounds are often the ones that have been subjected to alteration or destruction over the years. The GPR surveys in the northern portion of this site show an area with a cluster of several distinct and strong reflections that indicate the presence of intact subterranean chambers beneath the ground here. (Because of the near shallow presence of some of the subterranean chamber to the ground surface, some of them can actually be discovered by tapping ones foot on the ground to hear a subsurface echo of the ground at these locations).

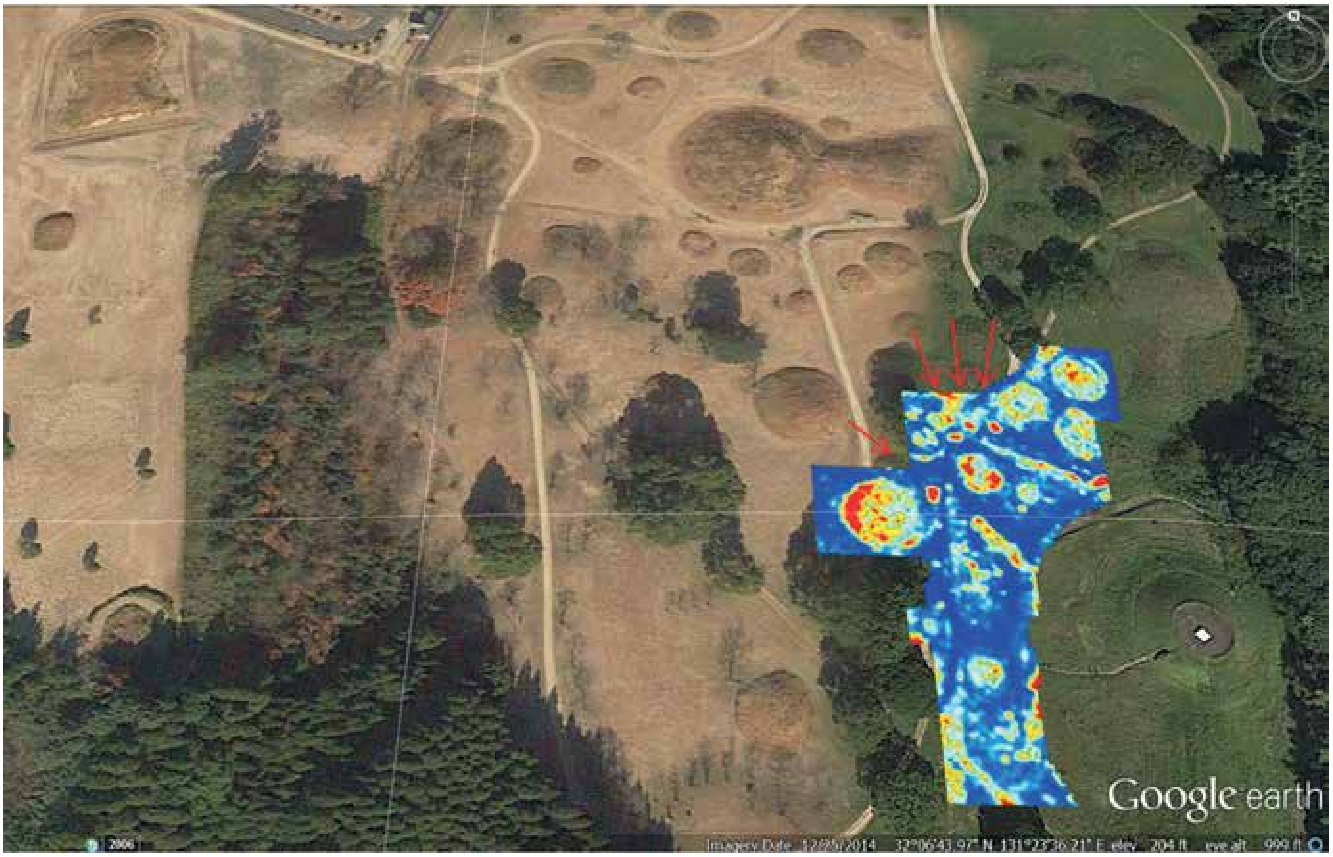

Figure 3: A depth slice from at Saitobaru made at 1.1-1.4 m and overlaid on Google Earth. In the northern location of the survey area a cluster of several strong distinct anomalies indicate the presence subterranean chamber burials. The large round reflection features are reflections from different soils comprising the burials mounds.

GPR Vector Imaging

When the sites surveyed with GPR have significant topographic changes, special analysis is made to adjust the radargrams and 3D volumes to account for roll, pitch and yaw of the antenna on the site. Although tilt meters are not currently placed on the equipment for real time monitoring for most applications today, GPR post processing using the surface normally determined from the topography is utilized to correct the data [2, 5]. This process assumes that antenna is orientated flat and in absolute contact with local mound surface during GPR profiling in the field.

Some unique problems can happen when roll/pitch/yaw corrections are made - radargrams can intersect and crossover regions where other nearby radargrams are projected. This can be seen in Figure 4 where vector imaging of the radargrams projected for Saitobaru burial mound #202 are shown. Typically in the imaging process the first pixel filled is used to represent a voxel element or an averaged voxel can also be used when crossovers are found to exist. Shown in Figure 5 are images of vector corrected level depth slices from the keyhole shaped burial mound. From the corrected dataset, a square burial pit on top of the mound (which can be seen on the 103 cm slice) could be measured and found to be approximately 5 m on a side. Deeper depths slices show the burial moats surrounding the mound which also appear to be flat-sided keyhole shaped without any corners on the flanks. The depth slice dataset includes reflections deeper than 6.4 m below the ground surface, and they do not indicate any subsurface void chambers at depth, suggesting that for this mound only a shallow surface burial of 1-2 m deep is present. Burial mound #202 is of a later date in the Kofun period and is identified by the nearly taller elevations of the keyhole bottom compared with the central round burial top.

Figure 4: Photograph of burial mound #202 at Saitobaru along with a vector corrected radargrams and level plane 3D corrected depth slice is shown. Some crossover regions where radargrams intersect with other nearby radargrams exist at a few locations on the deeper portions on mound #202 where the topographic slope is changing strongly.

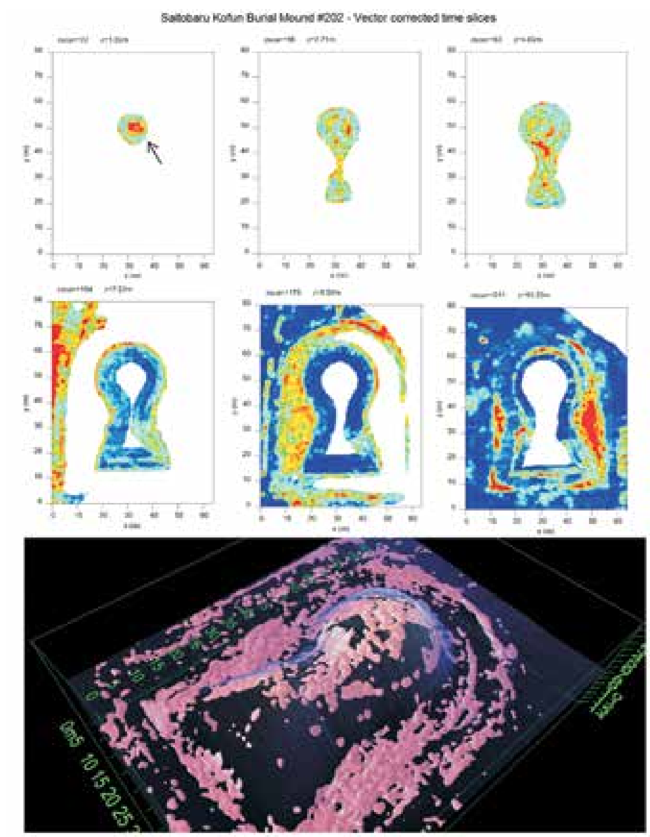

Figure 5: Vector corrected 2D level plane depths slices from 1.03-10.33 m are shown for Saitobaru Kofun Burial Mound #202 along with an isosurface rendering of the stronger reflections amplitudes in the 3D volume. The size of the square burial pit on the top of the mound can be estimated from the strong – square red anomaly seen on the 1.03 m depth slice and is about 5 meters.

Acknowledgements

GPR imaging and specialized vector imaging at Saitobaru National Kofun Burial Mounds were accomplished using GPR-SLICE v7.0 Software.

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LOOKING FOR LOST GRAVES

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Abstract

The identification of graves is an important issue at many historical cemeteries. Time and vandalism have often obliterated the trace of burials and the operator of the cemetery may not know where empty plots may still be available. Land development encroaching on an historical cemetery may also have to be careful about disturbing unmarked graves. In the extreme case where a cemetery needs to be relocated because of development, it is important to make sure that unmarked graves are not overlooked. As excavation is seldom a desirable solution to locating unmarked graves, methods of detecting burials from the ground surface can have an obvious benefit.

This paper is an update to a presentation made in 2003 at the Council for West Virginia Archaeology Spring Workshop where the three most commonly applied geophysical techniques (ground penetrating radar – GPR; magnetics; and resistivity/conductivity) were reviewed through case histories documenting the detection of graves. Over the past 10 or so years, the physics of detecting graves has not changed, but our ability to visualize the geophysical data has improved, in particular with respect to the GPR technique. Some new case histories demonstrate these changes.

Modern graves associated with concrete vaults are generally easy to identify on the basis of GPR reflections, but old graves where there is no vault or a casket has otherwise decomposed or was never present are much more challenging to map. In such cases, the main physical basis for grave detection is that grave shafts represent a disruption to the natural layering of the ground. Disruptions to soil layers can often be detected with GPR, although GPR usually best detects the base of a grave shaft. Graves are filled with a mix of the soil types excavated, so there is usually a physical contrast of the grave fill with natural soil. Graves are often manifested by magnetic lows because they disrupt the natural fabric of soil magnetization and are therefore delineated by magnetometry. Grave fill is not as dense as natural soil and can result in either resistivity highs or lows depending on site-specific conditions. The basic conclusion is that the detection of old graves is difficult, but usually achievable, especially when multiple techniques are applied. If a single technique is applied, and if field conditions permit, GPR is usually the most effective. Although individual graves can sometimes be identified with magnetics and resistivity, these techniques usually work best to give a geophysical framework to a cemetery, rather than identify individual burials.

Keywords: Historical Cemeteries, Ground Penetrating Radar (GPR), Magnetometry, Resistivity, Multiple Geophysical Techniques.

Introduction

Many old cemeteries have "lost" graves that can prove to be problems if they are accidentally disturbed. In many or most cases, church or family records are not precise in terms of knowing conclusively who is buried where. Assuming that massive excavations are not a good idea, the application of non-destructive means to locate unmarked graves can be clearly advantageous.

At the time this first review of grave detection was presented in 2003, the most commonly applied remote sensing technique for the detection of unmarked graves was dowsing (Figure 1). Unfortunately, the situation in 2015 has not changed. Dowsing, also known as rhabdomancy or divining, traditionally uses a forked stick, a pendulum, or a pair of rods (including the use of coat hangers) and movements of the device can indicate the presence of graves, or virtually any other buried object of interest. The mechanism behind the detection is believed to depend on energy fields unknown to science. Nearly everyone has met a person who at least claims to have some proficiency in the field of dowsing, although if asked to explain scientifically how the process works, they have no idea, but they know that it works for them. This subject is mentioned because a simple internet search will reveal that it is just as easy (and possibly easier) to find a "specialist" in dowsing than a geophysicist specializing in the detection of graves. A Google search undertaken at the time of writing this paper for the subject of "rhabdomancy for graves" identified as the first reference instructions as to how to detect graves on the basis of dowsing [1].

The problem is that few things capture a curious mind more easily than the unproven and esoteric, as described in May/June 2003 Archaeology in the Special Section entitled Seductions of Pseudoarchaeology [2]. Dowsing falls into the same category, even though there are certainly more followers of this form of pseudoscience than specialized geophysicists. The James Randi Educational Foundation (JREF) estimates that there are more than 20,000 dowsers operating in the United States alone, and even more in Western Europe [3]. Ankerberg and Weldon review dowsing in the context of New Age spiritualism and also confirm that there is no physical basis for dowsing, but the influence of dowsing is greater than most people realize [4]. JREF documents that dowsers have been subjected to many tests over the years and have performed no better than chance under controlled conditions. Scientific American as early as 1857 documented that divining rods were a deception [5], but people still wish to believe in pseudoscience as fact. JREF offers an award of $1,000,000 for anyone who can scientifically prove any paranormal ability and notes that some 80% of the applications for this challenge are for dowsing, mostly from honestly self-deluded people who are convinced they have this ability. None of the challenges have had any validity. As noted by the Romans: Homo vult decipi; decipiatur [Man wishes to be deceived; deceive him].

Figure 1: Most common technique for finding lost graves.

Returning to the realm of real science, geophysics can have potential success in detecting unmarked graves because of some general characteristics of grave shafts:

- Grave shafts disrupt natural soil layering (Figure 2). Techniques sensitive to mapping the continuity of soil horizons such as GPR can be effective.
- The in-fill of a grave shaft is usually an average of the physical properties of intact soil horizons, which means that if there are vertical soil changes, the fill will probably have some physical contrast with the natural ground.
- Grave fill can sometimes represent a disturbance to the magnetic fabric of natural soil and be manifested by a magnetic low. Graves themselves can be manifested by magnetic highs if ferrous metal is present.
- Grave fill is often of a lower density and higher porosity that can be manifested as either higher or lower resistivity depending on site-specific conditions, although the experience of the authors where soils contain clay is that grave shafts are usually a resistivity low, as also documented by Wood and Rush [6] and Simpson and Peterson [7]. If the grave shafts are brick-lined the anomalies are usually positive [8].

Three geophysical techniques have the greatest potential application in detecting unmarked graves: electrical measurement methods, ground penetrating radar (GPR) and magnetometry. The following sections review these techniques.

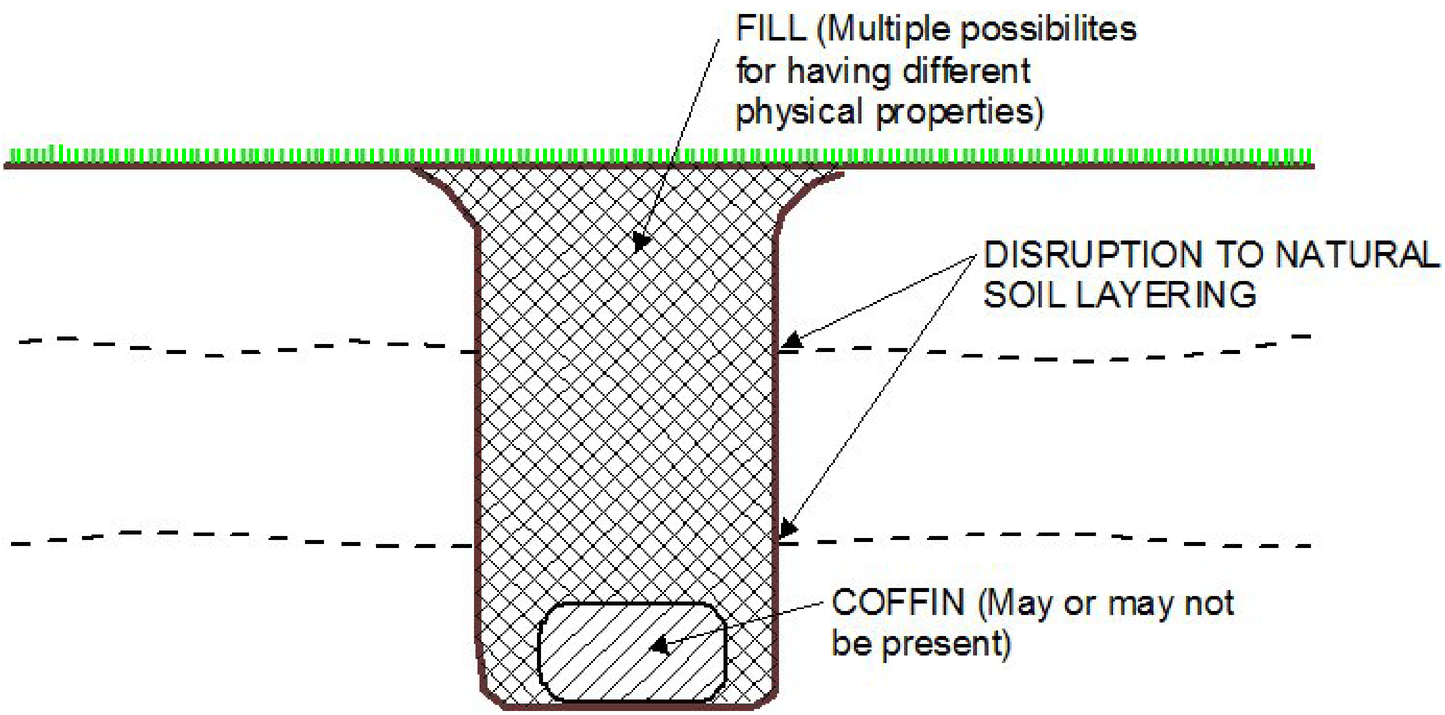

Figure 2: A grave as a geophysical target.

DC Resistivity

The purpose of DC electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the soil or rock. Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations, but the use of this method has been recently increased due to improvements in both data acquisition and processing technologies.

Multi-electrode systems have greatly improved the efficiency of data acquisition, as measurements can now be made automatically. Until recently, the DC resistivity method was limited by the need to perform complex calculations to model subsurface electrical properties.

With the development of high-speed PC computer systems and improved 2D and 3D processing software, this limitation has been greatly reduced and the technique can be used for the detection of graves (see Figure 3 for an example from the Monroeville, PA Historical Cemetery). Equipment costs for multi-electrode resistivity systems are quite expensive; however, and this type of survey is by no means routine. Variations in ground resistivity are more commonly mapped on the basis of resistance mapping with equipment such as a Geoscan RM15 and graves have been delineated with this technique.

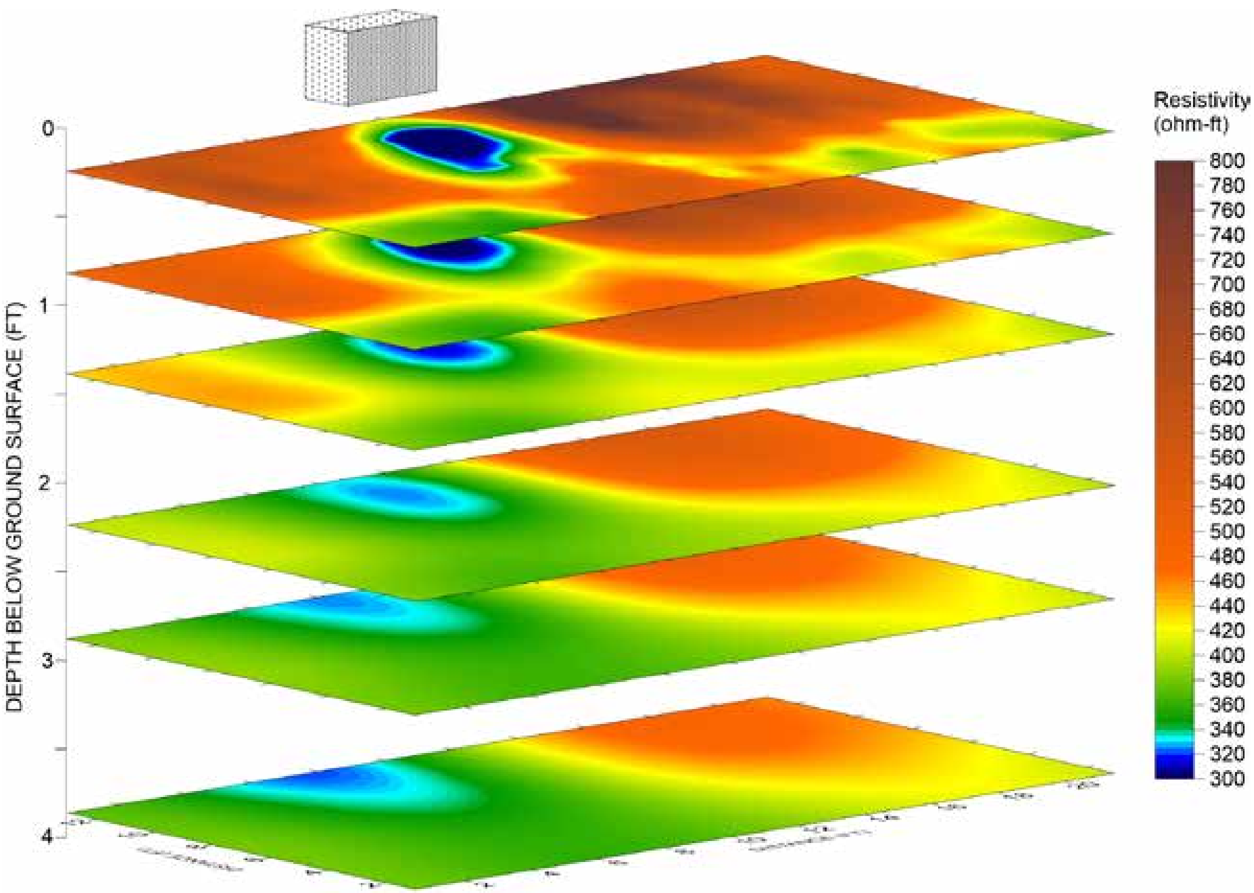

Figure 3: Results of 3D resistivity survey over a grave at the Monroeville, PA Historical Cemetery depicted as a series of horizontal sections produced using the RES3DINV program.

Magnetometry

The excavation of a grave shaft disturbs the magnetism that may be associated with natural soil, effectively reducing the magnetic susceptibility of the grave fill compared to the natural soil. A grave shaft can therefore sometimes be detected as a magnetic low. Alternatively, in cases where graves have been cut into magnetically inert material such as limestone and subsequently filled with soil from an external source, the signature from the grave can be a magnetic high (Figure 4, excavated graves shown on Figure 5). The main disadvantage to the magnetometer is the likely presence of other cultural interference, especially metal, commonly encountered in areas disturbed by man.

The authors' preferred instrument for the shallow, high resolution measurements associated with historical cemeteries is the cesium vapor gradiometer, a special form of magnetometer that contains two sensors mounted on an aluminum rod and separated vertically by at least 0.5 meters. The magnetic intensity recorded at the upper sensor is subtracted from the intensity at the lower sensor to determine the vertical magnetic gradient at each measurement point. The gradiometer is more sensitive to the location of shallow objects than a conventional magnetometer because the response of the instrument falls off as the inverse fourth power of distance, whereas intensity falls off as the inverse third power. This means that the gradient field that a shallow object will produce is a response to very shallow subsurface conditions and for this reason is commonly measured for archaeological studies. Graves (and frequently old excavation units left over from archaeological investigations) can be imaged by magnetic gradient.

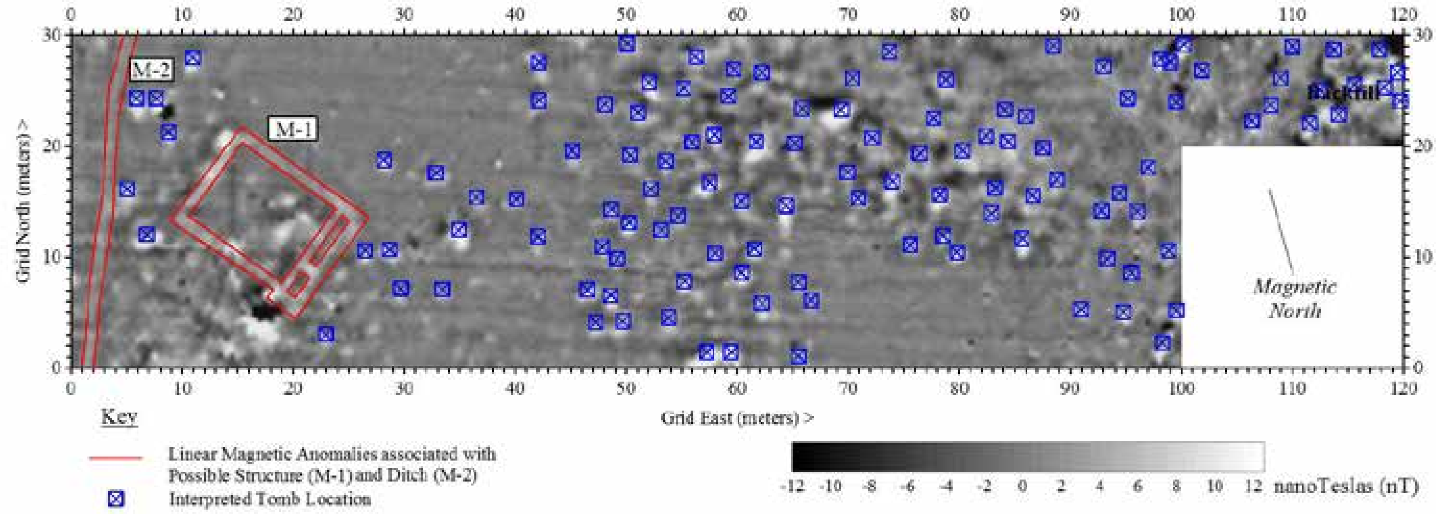

Figure 4: Magnetic gradient from ancient Greek ruins at Paestum, Italy. Numerous graves were identified from their magnetic signature, as well as a temple structure and an ancient road (the linear feature identified as a "ditch" proved to be a road).

Figure 5: Ancient graves excavated at Paestum, Italy.

Ground Penetrating Radar (GPR)

GPR offers the highest resolution of any geophysical method. In many cases, the time required for the acquisition of GPR profiles is minimal and subsurface profiles can be obtained in real time, making this tool very cost-effective. GPR works best in non-conductive soils, such as dry sand or sand saturated with fresh water. The least favorable condition occurs when the soils consist of wet, saturated clay, although this is not a major concern at the shallow depths associated with most burials. GPR surveys are often conducted as 2D profiles (example shown on Figure 6), but improvements in processing software over the past decade have made 3D imaging the preferred survey technique for mapping graves.

Graves can be identified on the basis of the disruption of soil horizons by the grave shaft. This assumes that the natural soil has discrete horizons that can be identified by GPR reflections, but in any case the base of a grave shaft is usually a good target. Vaults or air-filled caskets are excellent targets for GPR, if present. Although it is not possible to make guarantees, the GPR method is usually the most definitive technique in mapping unmarked graves.

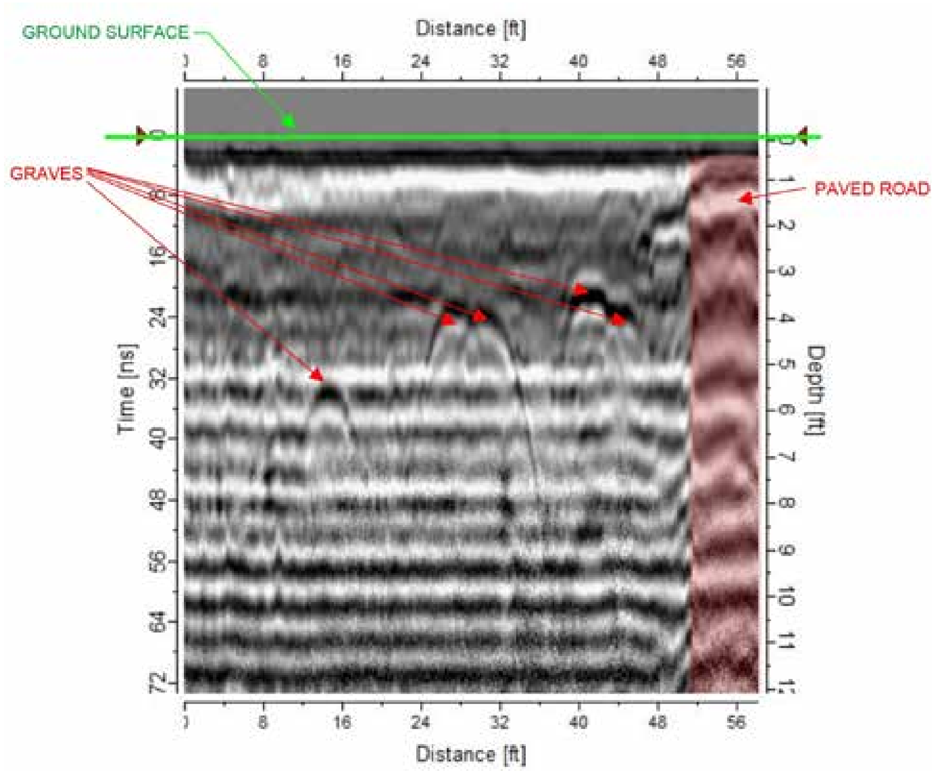

Figure 6: GPR profile over historic graves at the Beachwood, Ohio cemetery – several reflections are from graves where headstones are not present.

Application of Multiple Geophysical Techniques: Hill Historical Cemetery in Baden, Pennsylvania

The Hill Historical Cemetery in Baden, PA is located adjacent to a highway (Route 65) on a small hill on the eastern bank of the Ohio River about 21 miles downstream from Pittsburgh. The cemetery was created by the Hill family in the early 1800's, and contains the graves of many of the original settlers of Baden, including several veterans from the Revolutionary and Civil Wars. Due to several factors, including vandalism, many tombstones have been knocked over and several appear to be missing or mislocated. The scope of the geophysical investigation was twofold, to identify graves that are either unmarked or have inaccurate tombstone placement and also to delineate buildings and related structures associated with Legion Ville, a training camp constructed by General Anthony Wayne in 1792 and suspected of encroaching on the cemetery. Another factor to be considered in the interpretation of the data was that the site is near Logstown, a well-known settlement of Native Americans that was the location of early contact with European traders. The possibility that there could be evidence of prehistoric occupation of the cemetery site also needed to be considered.

Several geophysical techniques including a Geonics EM61 time-domain electromagnetic system for deep metal detection, magnetic gradiometry, and ground penetrating radar (GPR) were applied at the cemetery. The deep metal detection survey is not mentioned as a primary technique for identifying graves as metal is typically not a diagnostic feature of a grave. In this case, the metal detection was conducted to facilitate the interpretation of the magnetic data to distinguish which anomalies were due to metal and which could be interpreted in terms of a different cultural origin.

The survey was initiated with the time-domain metal detector. This determined a baseline from which the magnetic data could be interpreted. Magnetic data acquired with a Scintrex Smartmag cesium vapor gradiometer were interpreted in terms of subtle soil changes, such as associated with buried roads, graves, building foundations, or fire hearths. Finally, ground penetrating radar (GPR) was conducted using a RAMAC system to identify graves based on images from the coffins or on the basis of disturbances to soil horizons. The GPR data also provided supplementary information regarding structures and building foundations.

The interpretation of the geophysical data sets proved to be a challenging process. The site has a complex history of occupation probably beginning in prehistoric times and including the military training from the 1790s and the subsequent development of the Hill Cemetery. Each occupation left an imprint on subsurface conditions reflected in the geophysical results.

Interpretation of geophysical data was categorized into probable features (Figures 7 and 8):

- Possible prehistoric features - Features that could be related to prehistoric occupation are fire hearths. Hot fires cause soil to become magnetic and are normally marked by magnetic highs. The interpretation is not entirely straightforward, however, as small amounts of metal could also produce similar magnetic anomalies. To be able to identify features that could be fire hearths, the magnetic results were compared with the distribution of metal from the EM-61 readings.
- Possible Legion Ville structures - Prior to the survey, available information suggested that the cemetery could be the location of Redoubt No. 4. This part of the Legion Ville Camp was expected to be comprised of a blockhouse, probably with stone foundations, surrounded by a deep trench. This type of structure was not encountered. Nevertheless, the data do define what appear to be building foundations, best depicted by the magnetic gradient data. The overall pattern of the apparent structures is not one of a redoubt, but could be associated with barracks or stables. The distribution of shallow metal suggests that one of the structures could have been a forge.
- Roads and pathways - A N-S trending road is present at the eastern edge of the property that is unrelated to modern Route 65. Other, more subtle alignments of magnetic anomalies and GPR reflections define the presence of other roadways or pathways crossing the cemetery diagonally.
- Graves - Over 50 locations of ground disturbance that have the appearance of graves not associated with headstones are present across the site. In many cases there is evidence of the presence of graves at the ground surface, but in other cases there is no surficial evidence. Generally speaking, where a headstone is present there appears to be an associated grave.

An archaeological investigation to verify the geophysical interpretation is pending.

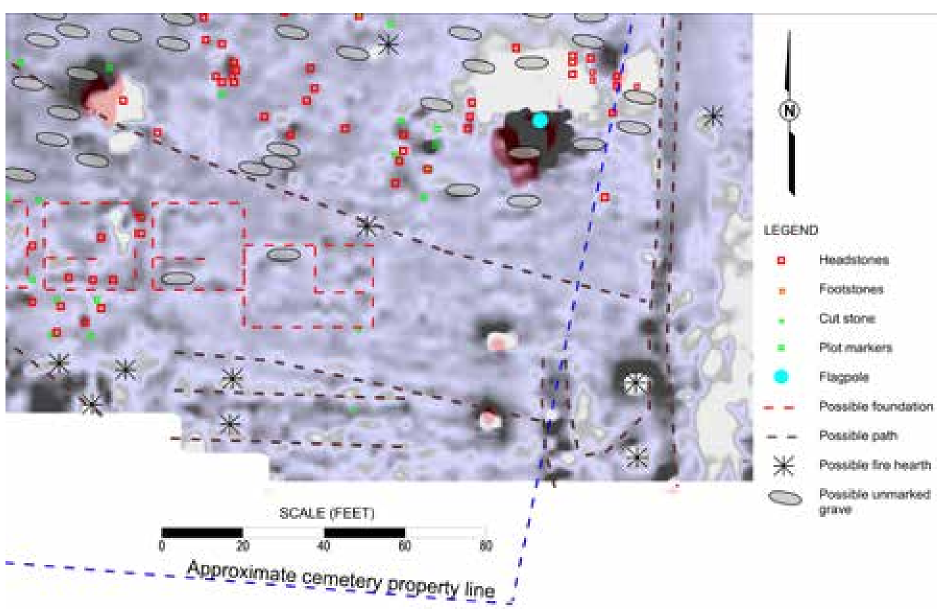

Figure 7: Magnetic gradient (350 nT) with interpretation at Hill Historical Cemetery (metal as defined by EM61 measurements is shaded red). Fire hearths are interpreted as magnetic anomalies not associated with metal.

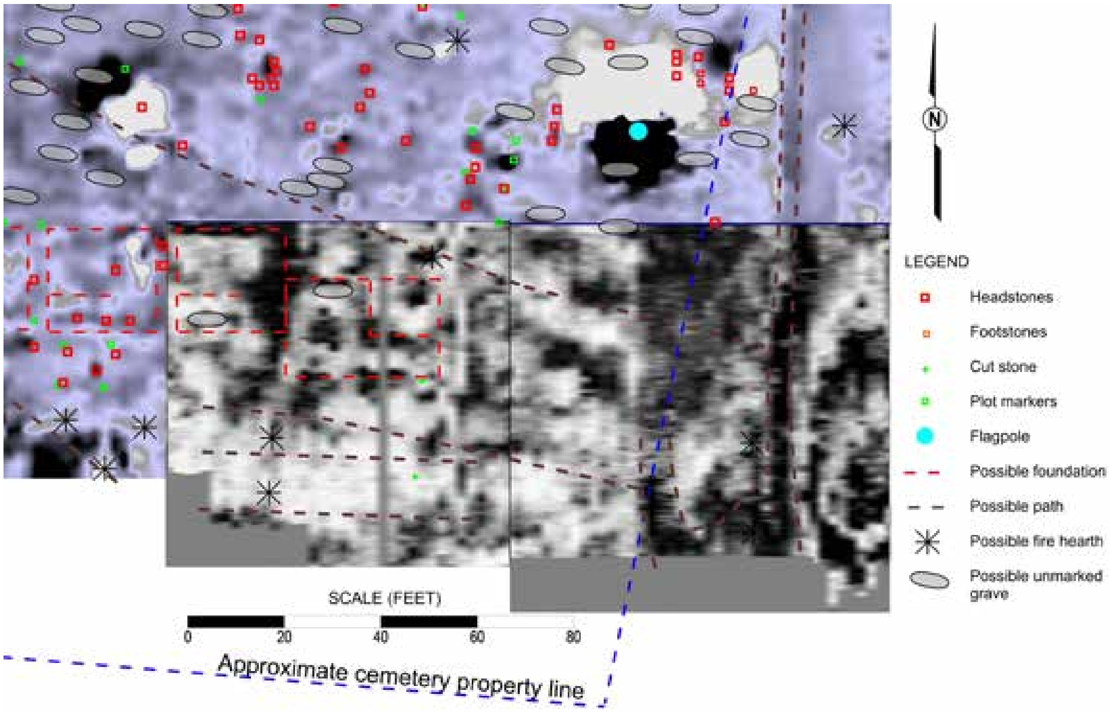

Figure 8: GPR time slice from depth of 3 – 4 feet at the Hill Historical Cemetery – the GPR proved the best technique for identifying graves. The identification of possible building foundations is also supported by the GPR.

Application of the 3D GPR Technique: Beachwood Historical Cemetery, Beachwood, Ohio

Beachwood Cemetery in Beachwood, Ohio is a site with a rich history, extending back to the early 19th century. The cemetery is historically significant because several groups of individuals are buried there including veterans of numerous wars starting with the Revolutionary War. Cemetery records, although probably incomplete, show a pattern of burials beginning with the first known burial in 1813 and increasing in number of burials per decade to a peak in the 1940s. Since that time the rate of burials has decreased to the point that the cemetery is effectively no longer being used. Part of the reason for this lack of use relates to the uncertainty in knowing whether or not a location has been previously occupied. The total number of known recorded burials in the Beachwood Cemetery is 567. Many of these are not expected to be associated with coffins or vaults, as records indicate that cremated remains were interred. There are also many infant burials that may or may not have been associated with significant underground containment. A 3D GPR survey was undertaken to determine the location of burials, but equally significant, the areas where graves are not expected to be present.

A MALÅ Geoscience X3M radar system was used for this investigation. The antenna was a shielded 250 MHZ antenna. The data were acquired along profiles separated by two to three feet. In total, the length of survey line was close to 8,000 feet. The data were processed such that interpretation could be made on the basis of visualizing the data both in terms of individual GPR profiles, as well as three-dimensional blocks. Data viewed as a horizontal surface depict the variations of the amplitude of reflected radar waves corresponding to a specific reflection time and are referred to as time slices (example shown on Figure 9). Each time slice corresponds to a specific depth in the soil.

The total number of probable burials at the Beachwood Cemetery identified by the GPR technique is 503. The total number of known burials including infants and burials of ash where subsurface evidence of burial might not be obvious is 567. Accordingly, the number of identified graves is reasonably consistent with the historical record. The number of high quality GPR reflections interpreted to originate from vaults or coffins that are still intact is 121. The number of burials since 1930 is reported to be 253, so it is clear that vaults were not always used for these burials. Many of the burials are reported to be infants, who may not have had special vaults and this may be the explanation. The cemetery is close to full capacity, but there are areas where the presence of an existing grave is highly unlikely. A portion of the interpreted results is provided on Figure 10.

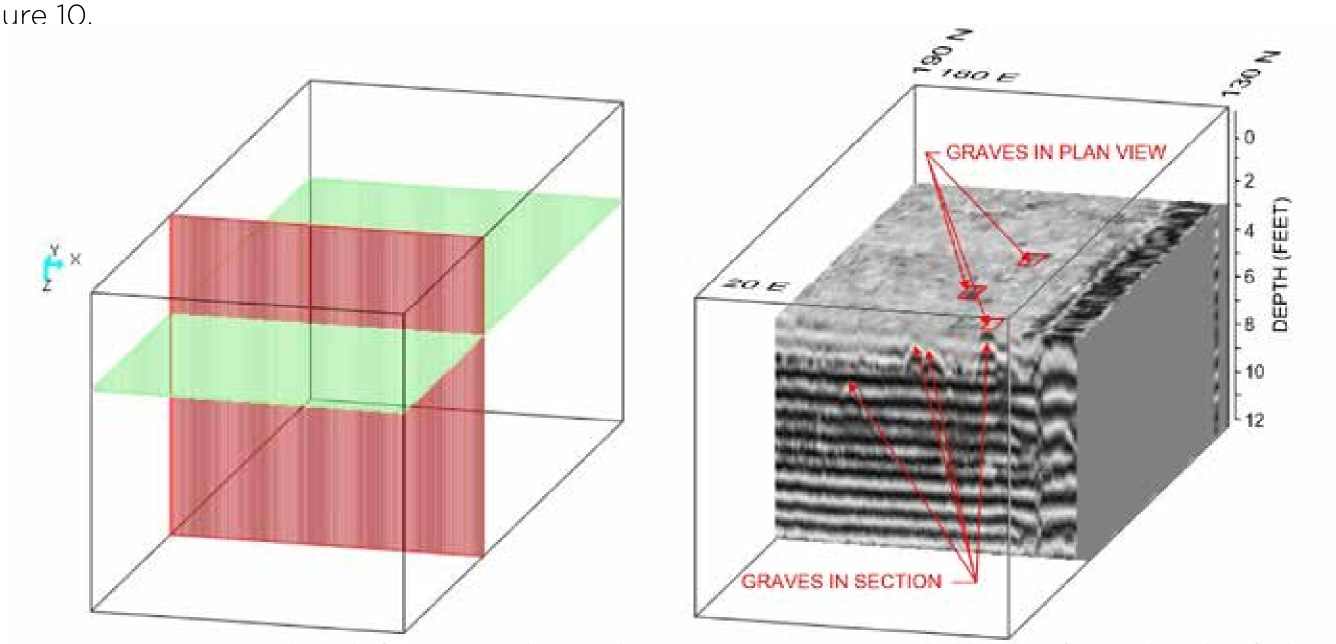

Figure 9: Example 3D block from Beachwood Cemetery Survey – time slice from depth of about three feet. Graves are identified by their hyperbolic reflections in cross section and the size and orientation of the grave is identified in plan view by looking at horizontal slices that intersect the grave reflections.

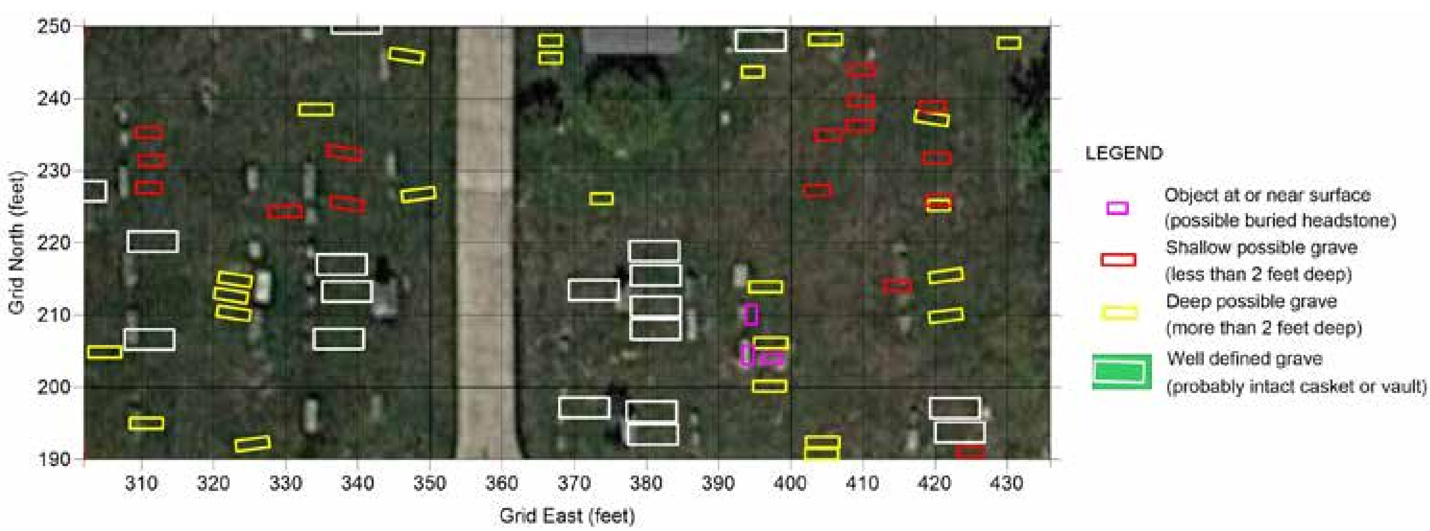

Figure 10: Portion of final results from Beachwood Cemetery Survey.

Diuguid Cemetery Near Ghent, Kentucky

This last case history is a good example of an investigation using the three principal methods discussed in this paper: GPR, magnetometry, and electrical resistance. It was cost-effective to use all three methods because of the small size of the site. The Diuguid Cemetery is a small 19th century family plot that needed to be relocated due to impending development. The survey area investigated consisted of a visible cemetery surrounded by a partially fallen stone wall and an area extending about 35 feet (10 meters) outside the walls. The walls enclosed a square approximately 13 meters per side. The northeast corner of the survey area had not been cleared because it was too steep. Geophysical data could not be collected over that section of the site.

Three techniques were employed: magnetic gradiometry, DC resistance and ground penetrating radar (GPR). Surficial metal affected the magnetic results, but in general magnetics were not diagnostic of the presence of graves, even where not affected by metal. The color image map of the resistance data collected using a Geoscan RM15 with a 0.5-meter electrode separation is shown on Figure 11 with areas of higher resistance shown in shades or yellow and red while areas of lower resistance are shown in shades of blue. The northeast part of the site appears to be lower resistance and is probably the result of geologic (soil) changes across the site rather than resulting from graves. Six resistance lows identified as possible graves were identified, two outside the walls and four inside, but resolution of the anomalies was such that results were not considered conclusive. GPR was acquired in a 3D mode along transects separated by 0.5 m. The time slice from a depth of approximately 0.5 m is presented on Figure 12, along with the anomalies that could be graves from both the GPR and resistance mapping methods. Several GPR reflections were identified that had the appearance of graves.

Another interesting observation can be made from the GPR depth slice image: a roughly rectangular area surrounding the walls can be seen. Three sides of the rectangular response oriented almost exactly to true north-south and east-west are delineated on the interpreted time slice. The resistance mapping also shows these borders, but to a lesser degree than the GPR time slice. Their orientation suggests that they have been related to property lines that were once different than the orientation of the cemetery. This is interpreted as an indication that the cemetery may have had a different size and orientation than indicated by the wall.

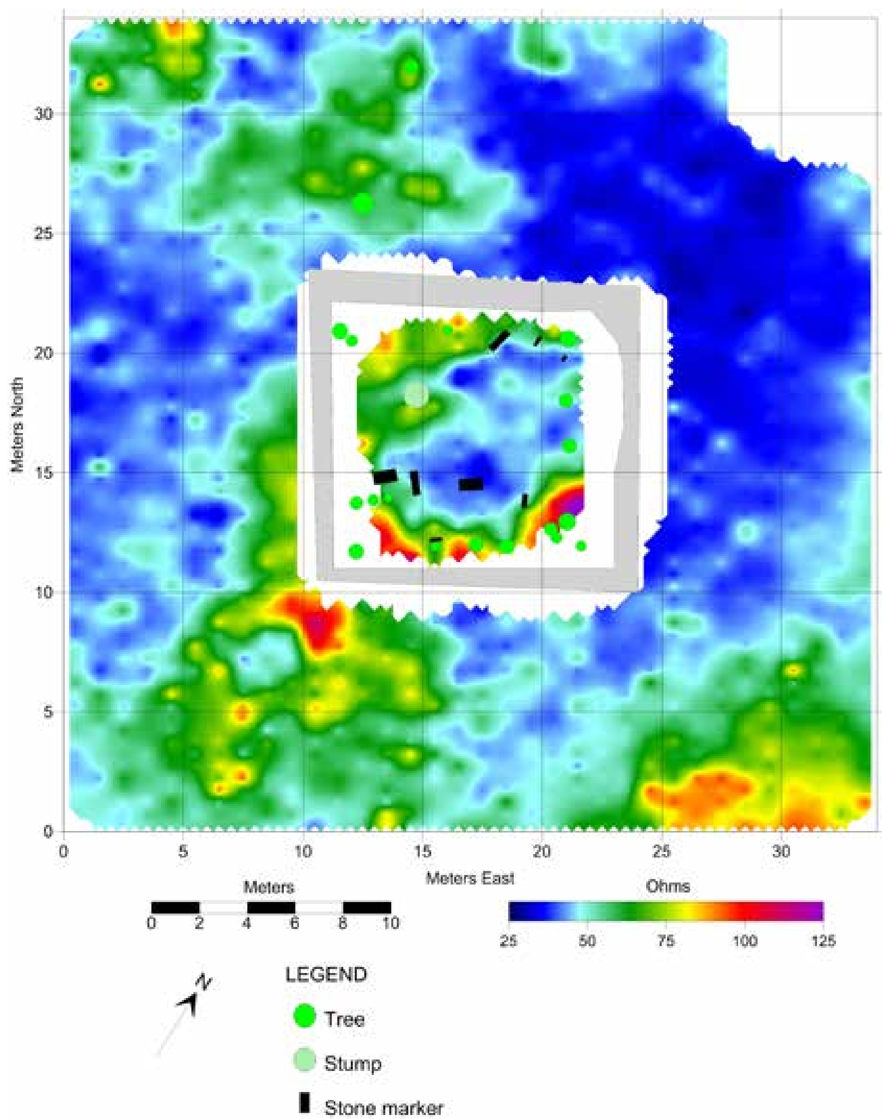

Figure 11: Variation in soil resistance at Diuguid Cemetery.

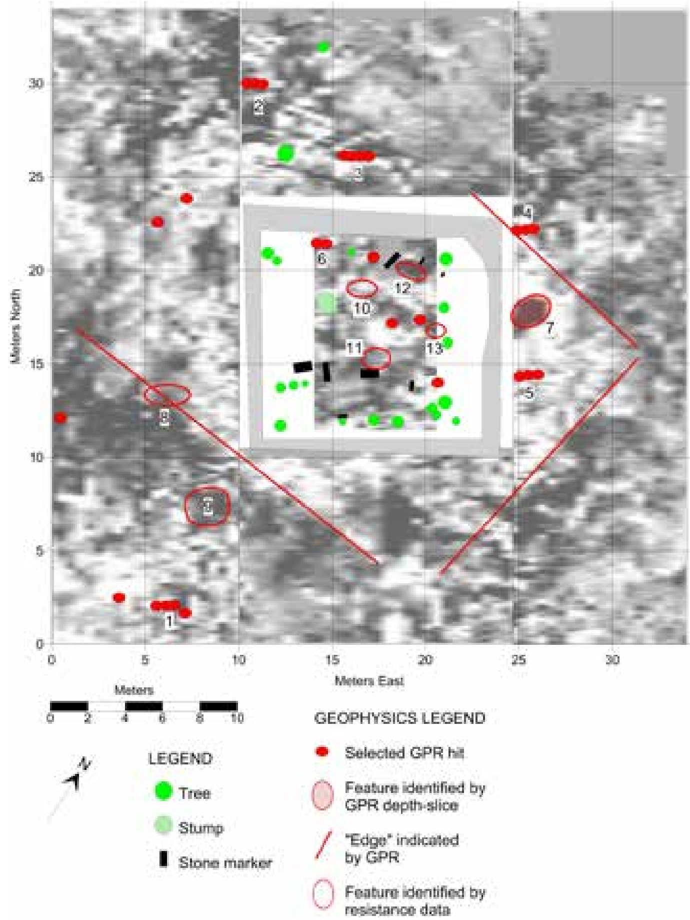

Figure 12: Geophysical interpretation of Diuguid Cemetery superimposed on GPR time slice from depth of 0.5 m.

Conclusions

It is the conclusion of the authors that the technique for mapping graves with the greatest likelihood of success is usually ground penetrating radar (GPR), but using multiple geophysical methods is recommended. GPR surveys conducted on the basis of 3D blocks are more readily interpretable than 2D profiles, where separate lines have to be visually correlated to identify graves. Electrical and magnetic measurements can also be effective for mapping graves, but are also useful to provide a framework for understanding the soil changes within a cemetery. If field conditions are favorable, careful interpretation of GPR sections and time slices is generally effective and sufficient for surveying an historical cemetery. Nevertheless, the identification of graves can be a complicated problem, depending on the age of the graves and soil conditions. Surface conditions, soil conditions, type and age of burial and condition of the coffins are all important factors in determining the effectiveness and costs of geophysical surveying. The most effective surveys will be multidisciplinary, where the geophysicist and historian or archaeologist are teamed together to interpret the data.

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GEOPHYSICAL INVESTIGATIONS AT THE COLD SPRINGS STATION SITE: A PONY EXPRESS STATION IN LINCOLN COUNTY, NEBRASKA

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Introduction

Between August 11 and 15, 2014, geophysical investigations were conducted at the Cold Springs Station site (25LN75) along the Pony Express National Historic Trail in Lincoln County, Nebraska (Figure 1). Two areas identified during the metal detection inventory by the University of Nebraska-Lincoln (UN-L) archaeological field school as building locations and trail swales (eroded swaths of passage) were investigated with magnetic and resistance survey techniques. These techniques offered inexpensive, rapid, and relatively non-destructive and non-invasive methods of identifying buried archaeological resources and site patterns and provided an efficient means for sampling the project area.

The Pony Express began its first mail ride on April 3, 1860, from St. Joseph, Missouri. The Pony Express reached San Francisco on April 14, 1860. During the next eighteen months, express riders carried mail between the eastern United States and California. The Pony Express was officially discontinued on October 26, 1861, with the completion of the transcontinental telegraph. Operations were divided into five divisions with Division One consisting of the stations between St. Joseph and Fort Kearney, Division Two consisting of stations between Fort Kearney and Horseshoe Station near Fort Laramie, Division Three consisting of the stations between Horseshoe Station and Salt Lake City, Division Four consisting of stations between Salt Lake City and Roberts Creek, and Division Five consisting of stations between Roberts Creek and Sacramento. The mail between Sacramento and San Francisco was generally carried by steamboat. The Pony Express trail followed portions of the Oregon, Mormon, and California trails

The route consisted of larger home stations located approximately 65 to 100 miles apart. The home stations were often associated with the existing stagecoach stations. Between the home stations were smaller relay rider or swing stations located approximately 20 to 25 miles apart at first but changed to 12 to 15 miles apart. It required approximately 75 horses to make a one-way mail run. Approximately 80 riders were hired by Russell, Majors, and Waddell (an American West freighting and staging firm that operated from 1854 to 1862).

The Cold Springs Station was a relay rider station near present day North Platte, Nebraska, in the Division Two set of stations between Fort Kearny in Nebraska and Horseshoe Creek in Wyoming. The Cold Springs Station site, 25LN75, was located in a hayfield on the south side of the South Platte River (Figure 2). The geophysical results provided complementary data on the building locations associated with the relay station on the Pony Express trail and on the trail swales associated with the overland Pony Express, Oregon, and California trails.

Keywords: Pony Express, Relay Station Building Locations, Trail Swales, Magnetic Survey, Resistivity Survey.

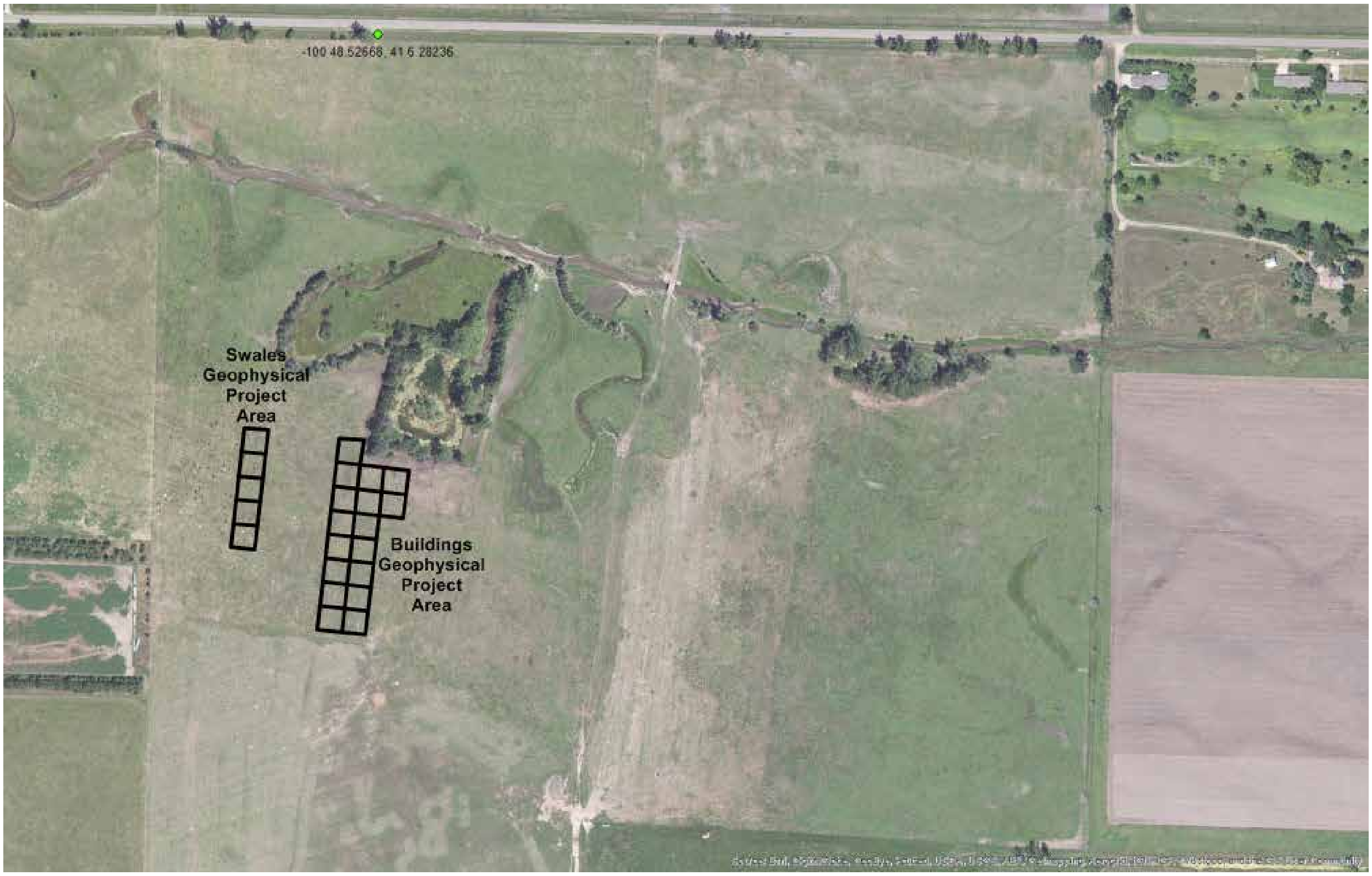

Figure 1: Location of the geophysical project areas at the Cold Springs Station site along the Pony Express National Historic Trail five kilometers southwest of North Platte in Lincoln County, Nebraska.

Figure 2: General view of the Cold Springs Station site in Lincoln County, Nebraska.

Geophysical Project Area Layout

The two areas identified by the UN-L metal detection survey were selected for the current geophysical survey. The geophysical grid for the Buildings and Swales Geophysical Project Areas were staked out with a robotic total station (Figure 3). The Building Geophysical Project Area consisted of thirteen 20-m by 20-m grid units while the Swales Geophysical Project Area contained five 20-m by 20-m grid units (Figure 4). The geophysical investigations covered 7,200 m^2 or 1.78 acres. Survey ropes were used to guide the survey traverses during the data collection phase of the geophysical survey (Figure 5). The geophysical survey grid corner stakes were mapped with a global positioning system (GPS) handheld receiver and external antenna along with other surface features. After the GPS survey data was post processed, the corrected data were exported to mapping software for final display (Figure 6).

Figure 3: Staking out the geophysical grids with a robotic station and prism.

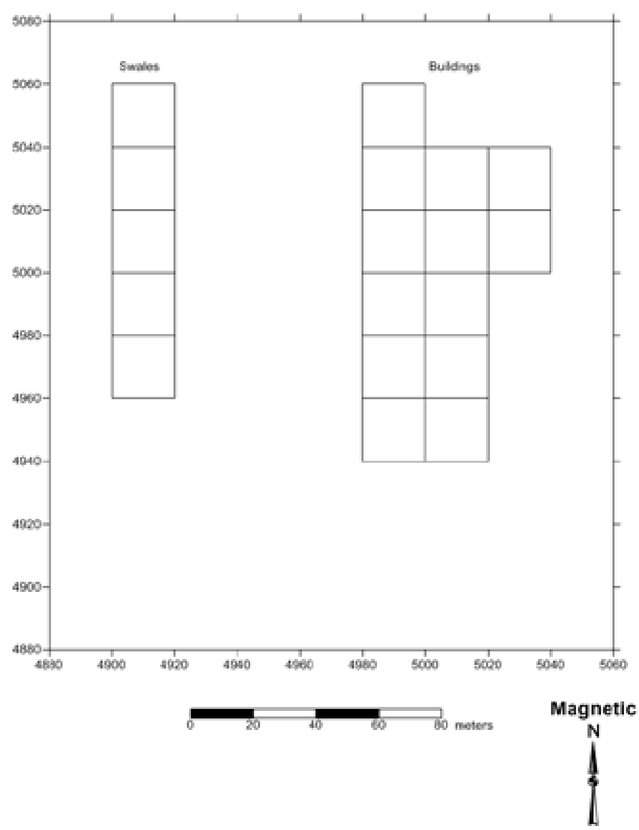

Figure 4: Geophysical project areas at the Cold Springs Station site.

Figure 5: Laying out the geophysical survey ropes on the geophysical project area.

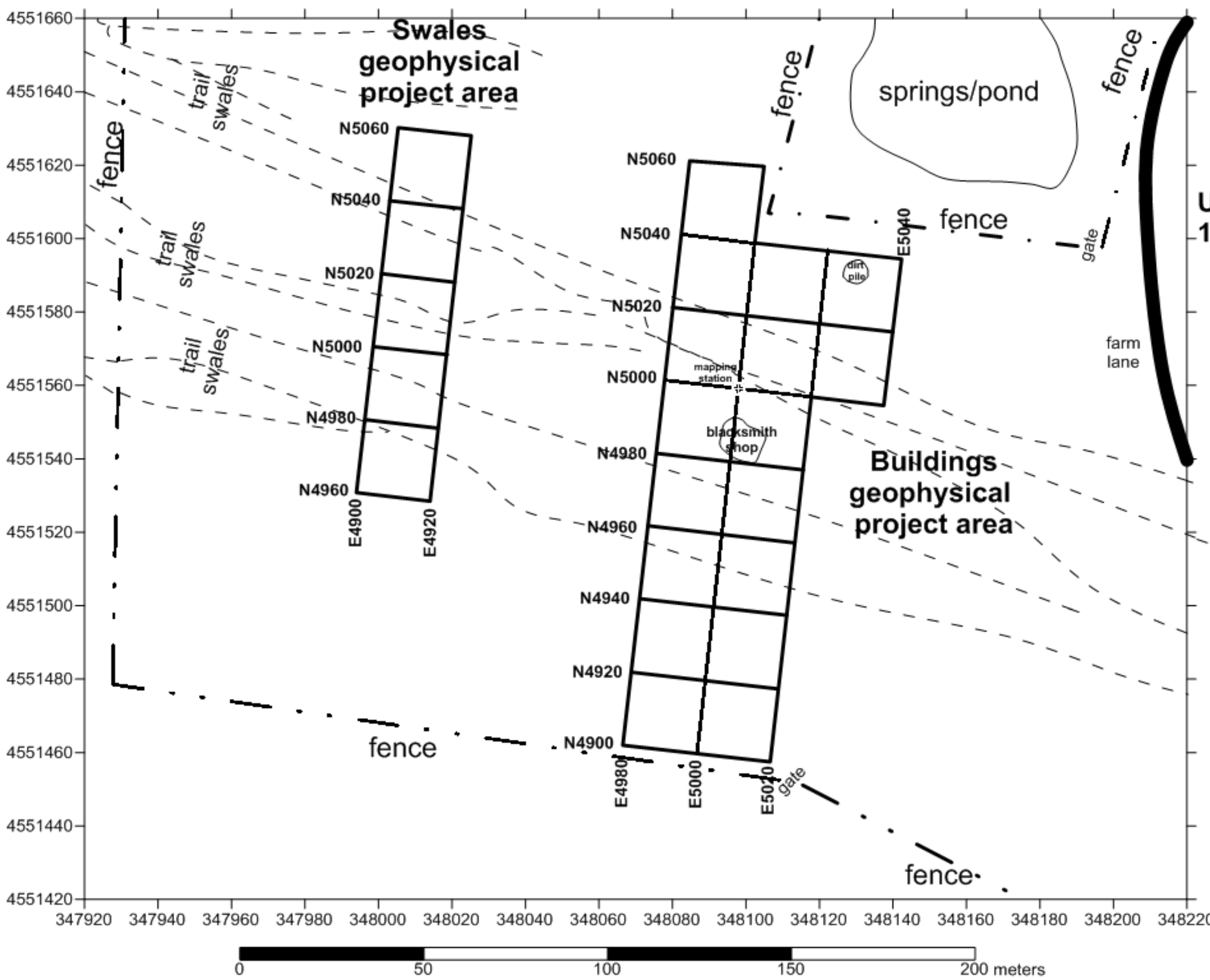

Figure 6: The Buildings and Swales Geophysical Project Areas.

Geophysical Prospection Techniques

Geophysical prospection techniques available for archaeological investigations consist of a number of techniques that record the various physical properties of earth, typically in the upper couple of meters; however, deeper prospection can be utilized if necessary. Geophysical techniques are divided between passive techniques and active techniques. Passive techniques are primarily ones that measure inherently or naturally occurring local or planetary fields created by earth related processes under study (Heimmer and DeVore, 2000; Kvamme, 2001). The primary passive method utilized in archeology is magnetic surveying. Other passive methods with limited archaeological applications include self-potential methods, gravity survey techniques, and differential thermal analysis. Active techniques transmit an electrical, electromagnetic, or acoustic signal into the ground (Heimmer and DeVore, 2000; Kvamme, 2001). The interaction of these signals and buried materials produces altered return signals that are measured by the appropriate geophysical instruments. Changes in the transmitted signal of amplitude, frequency, wavelength, and time delay properties may be observable. Active methods applicable to archaeological investigations include electrical resistance/resistivity, electromagnetic conductivity (including ground conductivity and metal detectors), magnetic susceptibility, and ground penetrating radar. Acoustic active techniques, including seismic, sonar, and acoustic sounding, have very limited or specific archaeological applications. Additional information on the basic geophysical techniques used during the present survey may be found in publications by Arnold Aspinall, Chris Gaffney, and Armin Schmidt (2008); Bruce Bevan (1991,1998); Anthony Clark (2000); Christopher Carr (1982); Andrew David (1995,2001); Andrew David, Neil Linford, and Paul Linford (2008); Chris Gaffney and John Gater (2003); Chris Gaffney, John Gater, and Sue Ovenden (1991,2002); Don H. Heimmer and Steven L. De Vore (2000); Kenneth Kvamme (2001,2003,2005,2006a,2006b); John Oswin (2009); Armin Schmidt (2013); I. Scollar, A. Tabbagh, A. Hesse, and I. Herzog (1990); Lewis Somers (2006); John Weymouth (1986); and Alan J. Witten (2006).

Magnetic Survey

A magnetic survey is a passive geophysical prospection technique used to measure the earth's total magnetic field at a point location. Its application to archeology results from the local effects of magnetic materials on the earth's magnetic field. These anomalous conditions result from magnetic materials and minerals buried in the soil matrix. Iron artifacts have very strong effects on the local earth's magnetic field. Other cultural features, which affect the local earth's magnetic field, include fire hearths and soil disturbances (e.g., pits, mounds, wells, pithouses, and dugouts), as well as geological strata. Magnetic field strength is measured in nanoteslas (Sheriff, 1973). In North America, the earth's magnetic field strength ranges from 40,000 to 60,000 nT with an inclination of approximately 60° to 70° (Milsom, 20033; Weymouth, 1986). The project area has a magnetic field strength of approximately 56,100 nT (Peddie, 1992) with an inclination of approximately 69.05° (Peddie and Zunde, 1988). Magnetic anomalies of archaeological interest are often in the 35 nT range, especially on historic sites. Target depth in magnetic surveys depends on the magnetic susceptibility of the soil and the buried features and objects. For most archaeological surveys, target depth is generally confined to the upper one to two meters below the ground surface with three meters representing the maximum limit (Clark, 2000; Kvamme, 2001). Magnetic surveying applications to archaeological investigations have included the detection of architectural features, soil disturbances, and magnetic objects/artifacts (Bevan, 1991; Clark, 2000; Gaffney et al., 1991; Heimmer and DeVore, 2000; Weymouth, 1986).

A single fluxgate gradiometer (Figure 7) was used during the magnetic survey of the two geophysical project areas at the Cold Springs Station site along the Pony Express National Historic Trail in Lincoln County, Nebraska. The magnetic survey for the single fluxgate gradiometer was designed to collect eight samples per meter along 1.0-meter traverses or eight data values per square meter throughout the entire geophysical project areas. The data were collected in a zigzag fashion with the surveyor alternating the direction of each traverse across the grid.

Figure 7: Conducting the magnetic survey with the single fluxgate gradiometer in the Buildings Geophysical Project Area.

Resistance Survey

The resistance survey is an active geophysical technique, which injects a current into the ground. Resistance or resistivity changes result from electrical properties of the soil matrix. Changes are caused by materials buried in the soil, differences in soil formation processes, or disturbances from natural or cultural modifications to the soil. In archeology, the instrument is used to identify areas of compaction and excavation, as well as buried objects such as brick or stone foundations. It has the potential to identify cultural features that are affected by the water saturation in the soil, which is directly related to soil porosity, permeability, and chemical nature of entrapped moisture (Clark 2000). Its application to archeology results from the ability of the instrument to detect lateral changes on a rapid data acquisition, high resolution basis, where observable contrasts exist. Lateral changes in anthropogenic features result from compaction, structural material changes, buried objects, excavation, habitation sites, and other features affecting water saturation. The resistivity survey may sometimes detect the disturbed soil matrix within the grave shaft.

The resistance meter uses the multiple probe array with a multiplexer in order to collect more than one reading at each station along the traverse. The two-meter beam is attached to the base of the frame for the four parallel twin spacings. The current and voltage probes are located on a mobile frame, which is moved around the site (Figure 8). Two additional probes are located away from the survey area, which also consists of a current probe and voltage probe. Each set of mobile probes are set 0.5 meters apart on the multiprobe array frame. The remote probes are set a distance 30 times the mobile probe separation at the geophysical project area from the nearest point on the grid units or 15 meters for the 0.5-m mobile probe separation. The probes on the frame are separated by 0.5 meters.

The resistance survey was designed to collect two samples per meter along 0.5-meter traverses or four data value per square meter across the two geophysical project areas at the Cold Springs Station site. The data were collected in a zigzag fashion with the surveyor maintaining the alternating the direction of travel for each traverse across the grid.

Figure 8: Conducting the resistance survey with the resistance meter, multiplexer and 4 parallel twin probe array in the Swales Geophysical Project Area.

Geophysical Data Processing

Processing of geophysical data requires care and understanding of the various strategies and alternatives (Kvamme, 2001; Music, 1995; Neubauer et al., 1996). Roger Walker and Lewis Somers (Geoscan Research, 2004, 2005) provide strategies, alternatives, and case studies on the use of several processing routines commonly used to process magnetic, resistance, and conductivity data in the GEOPLOT software. David et al. (2008) presents a basic description of steps involved in the processing of magnetic, resistance, and ground penetrating radar data. Dr. Kenneth Kvamme (2001) also provides a series of common steps used in computer processing of geophysical data:

Concatenation of the data from individual survey grids into a single composite matrix;
Clipping and Despiking of extreme values (that may result, for example, from introduced pieces of iron in magnetic data);
Edge Matching of data values in adjacent grids through balancing of brightness and contrast (i.e., means and standard deviations);
Filtering to emphasize high-frequency changes and smooth statistical noise in the data;
Contrast Enhancement through saturation of high and low values or histogram modification;
and ***Interpolation*** to improve image continuity and interpretation.

It is also important to understand the reasons for data processing and display (David et al., 2008; Gaffney et al., 1991). They enhance the analyst's ability to interpret the relatively huge data sets collected during the geophysical survey. The type of display can help the geophysical investigator present his interpretation of the data to the archeologist who will ultimately use the information to plan excavations or determine the archaeological significance of the site from the geophysical data.

Processing Single Fluxgate Gradiometer Data

Upon completion of the magnetic survey of the end of the each day with the single fluxgate gradiometer, the data were downloaded to a field laptop computer and processed in a geophysical processing program. The grid data files were transformed into composite files for the two project areas. The zero mean traverse was applied to remove any traverse discontinuities that may have occurred from operator handling or heading errors in the two data sets. The magnetic data from the magnetic survey of the Buildings Geophysical Project Area after the application of the zero mean traverse operation ranged from -204.7 nT/0.5m to 204.7 nT/0.5m with a mean of 0.17 nT/0.5m and a standard deviation of 7.031 nT/0.5m. The magnetic data from the magnetic survey of the Swales Geophysical Project Area after the application of the zero mean traverse operation ranged from -105.0 nT/0.5m to 36.5 nT/0.5m with a mean of -0.01 nT/0.5m and a standard deviation of 1.981 nT/0.5m. Upon completion of the zero mean traverse function, the data sets were interpolated by expanding the number of data points in the traverse direction and by reducing the number of data points in the sampling direction to provide a smoother appearance in the data set and to enhance the operation of the low pass filter. This changed the original 8 x 1 data point matrices into 4 x 4 data point matrices. The low pass filter was then applied over the entire data set for each project area to remove any high frequency, small scale spatial detail. This transformation resulted in the improved visibility of larger, weak archaeological features. The data were then exported as a data file to a contouring and 3D surface mapping program for final display (Oswin, 2009). Image and contour maps of the single fluxgate gradiometer data were generated for the two geophysical project areas at the Cold Springs Station site (Figures 9 and 10).

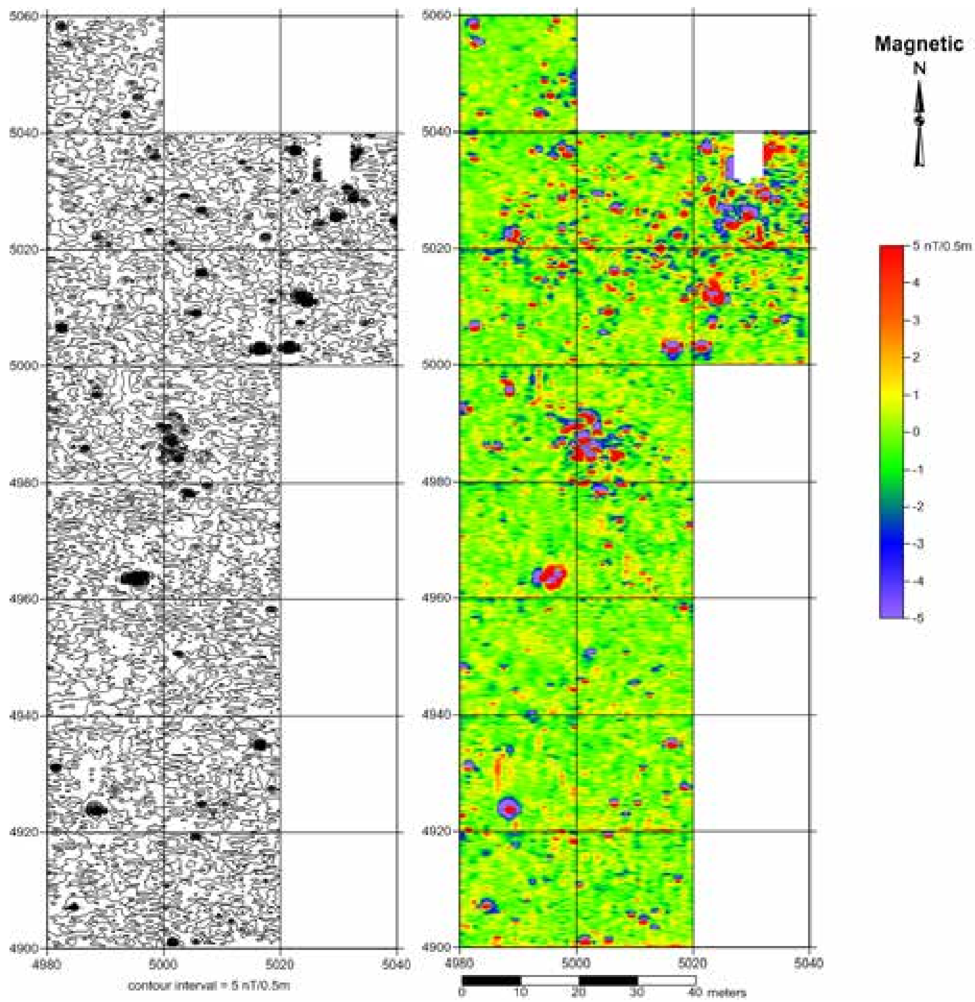

Figure 9: Image and contour plots of the magnetic data from the Buildings Geophysical Project Area.

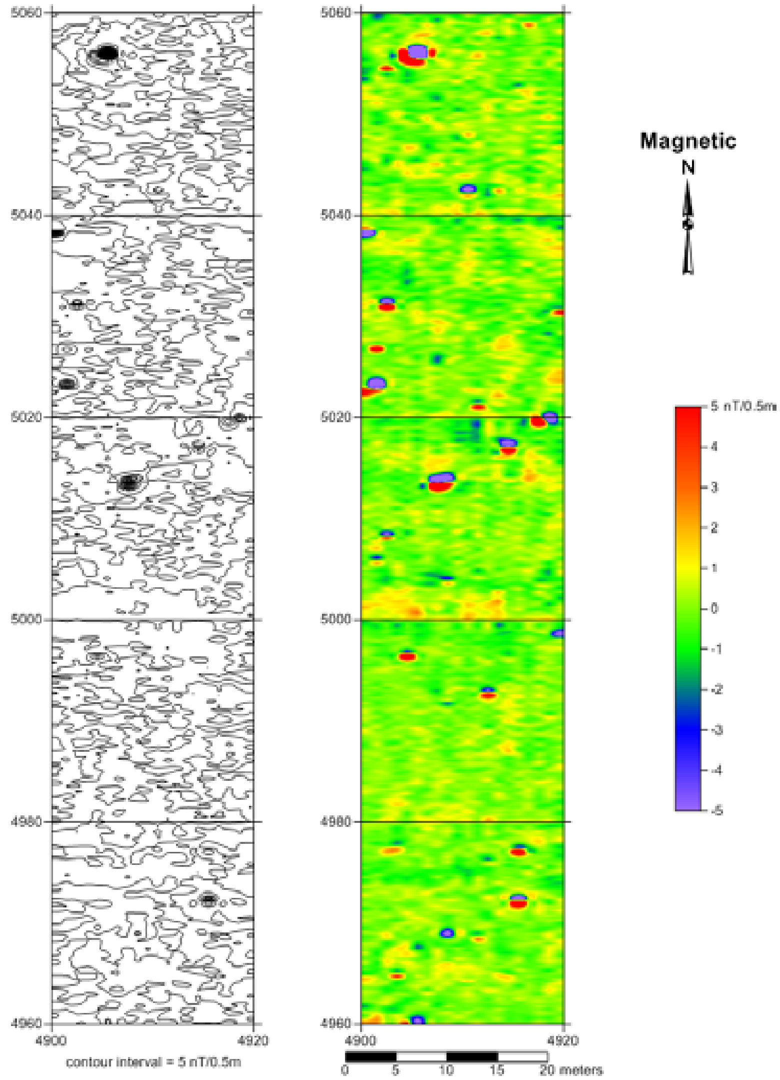

Figure 10: Image and contour plots of the magnetic data from the Swales Geophysical Project Area.

Processing Resistance Data

Upon completion of the resistance surveys of the two geophysical project areas at the Cold Springs Station site, the data were downloaded to a field laptop computer and processed. The grid files were combined to a form composite file. Erroneous data resulting in the faulty insertion of negative values were replaced. The resulting files for the resistance data were also despiked to remove erroneous spike or high measurements detected in the data set. The resistance data were converted to apparent resistivity. The apparent resistivity data from the resistance survey ranged from 31.4 ohm-meters to 641.2 ohm-meters with a mean of 225.92 ohm-meters and a standard deviation of 112.002 ohm-meters for the resistivity survey at the Buildings Geophysical Project Area. The apparent resistivity data from the resistance survey ranged from 31.4 ohm-meters to 641.2 ohm-meters with a mean of 225.92 ohm-meters and a standard deviation of 112.002 ohm-meters for the resistivity survey at the Swales Geophysical Project Area. The interpolation routine was applied to the data set to arrange the original 2 x 2 data matrix set to an equally spaced 4 x 4 square matrix. A high pass filter was then applied over the composite data sets. The high pass filter was used to remove low frequency, large scale spatial detail such as a slowing changing geological 'background' trend. The data were then exported into the mapping program for final display (Oswin, 2009). Image and contour maps of the resistance data were generated for the survey area (Figures 11 and 12).

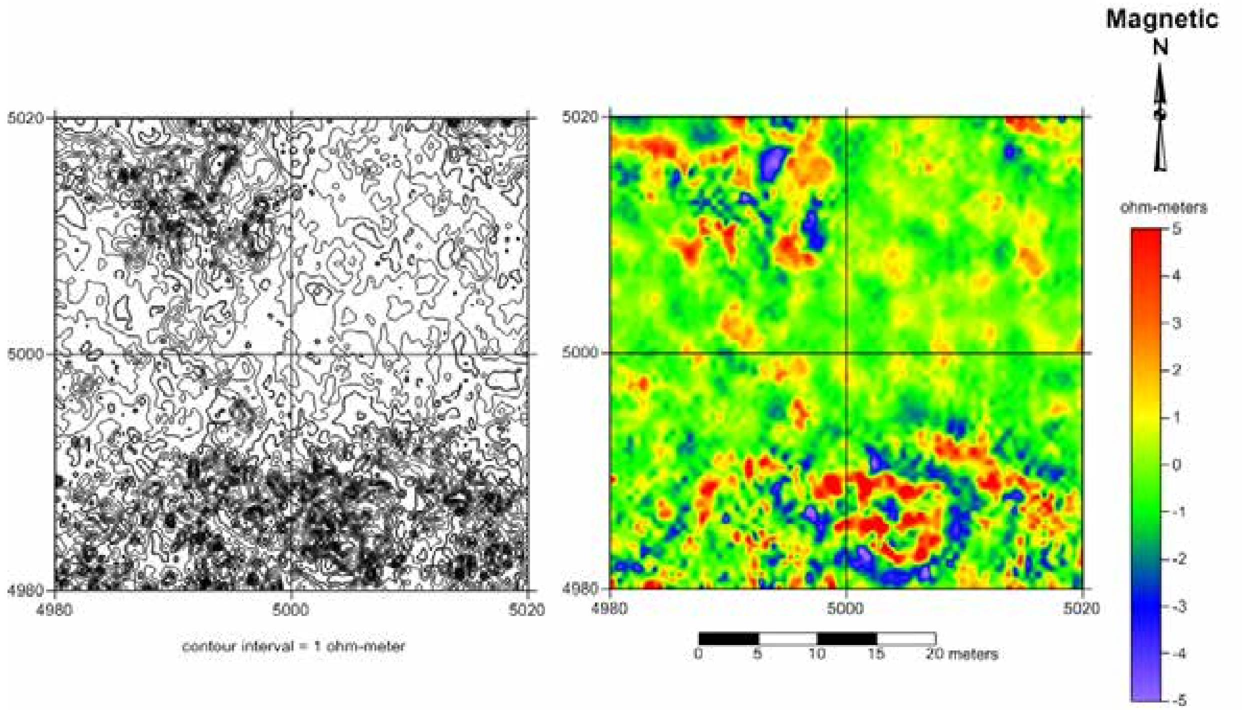

Figure 11: Image and contour plots of the resistivity data from the Buildings Geophysical Project Area.

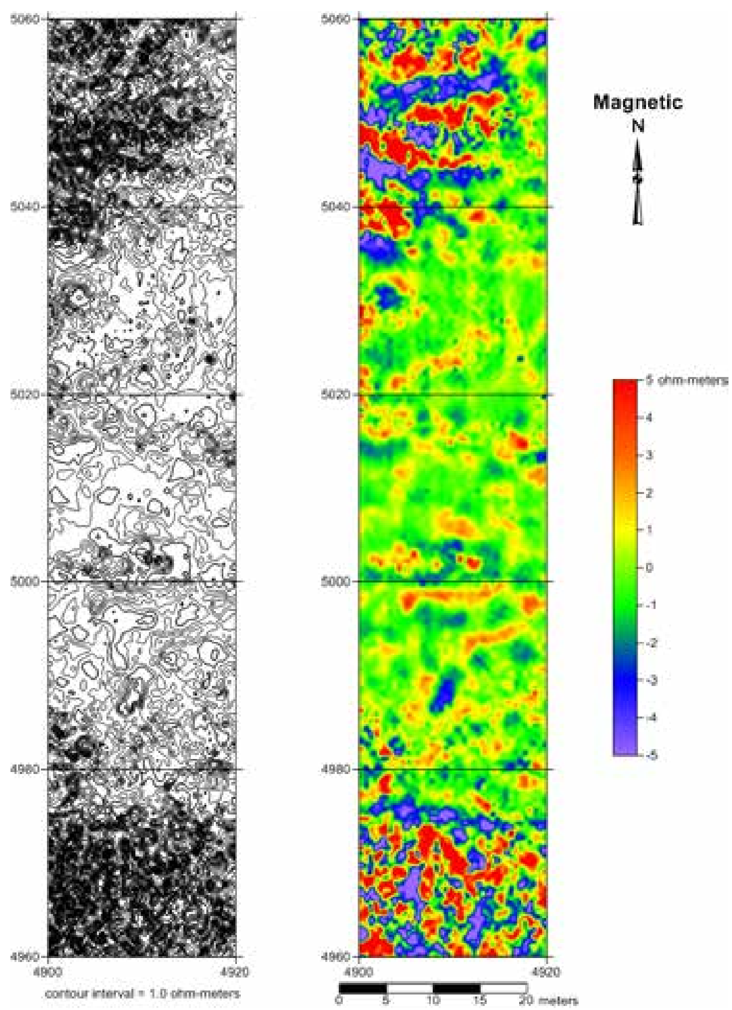

Figure 12: Image and contour plots of the resistivity data from the Swales Geophysical Project Area.

Geophysical Data Interpretations

Andrew David (1995) defines interpretation as a "holistic process and its outcome should represent the combined influence of several factors, being arrived at through consultation with others where necessary." Interpretation may be divided into two different types consisting of the geophysical interpretation of the data and the archaeological interpretation of the data. At a simplistic level, geophysical interpretation involves the identification of the factors causing changes in the geophysical data. Archaeological interpretation takes the geophysical results and tries to apply cultural attributes or causes. In both cases, interpretation requires both experience with the operation of geophysical equipment, data processing, and archaeological methodology; and knowledge of the geophysical techniques and properties, as well as known and expected archeology. Although there is variation between sites, several factors should be considered in the interpretation of the geophysical data. These may be divided between natural factors, such as geology, soil type, geomorphology, climate, surface conditions, topography, soil magnetic susceptibility, seasonality, and cultural factors including known and inferred archeology, landscape history, survey methodology, data treatment, modern interference, etc. (David, 1995; David et al., 2008). The grouping of anomalies or pattern recognition is also an important aspect of interpretation. It should also be pointed out that refinements in the geophysical interpretations are dependent on the feedback from subsequent archaeological investigations. The use of multiple instrument surveys provides the archeologist with very different sources of data that may provide complementary information for comparison of the nature and cause (i.e., natural or cultural) of a geophysical anomaly (Clay, 2001). Each instrument responds primarily to a single physical property: magnetometry to soil magnetism, electromagnetic induction to soil electrical conductivity, resistivity to soil electrical resistance, and ground penetrating radar to dielectric properties of the soil to (Weymouth, 1986).

Interpreting the Magnetic Data

Interpretation of the magnetic data (Bevan, 1998) from the project requires a description of the buried archaeological feature of object (e.g., its material, shape, depth, size, and orientation). The magnetic anomaly represents a local disturbance in the earth's magnetic field caused by a local change in the magnetic contract between buried archaeological features, objects, and the surrounding soil matrix. Local increases or decreases over a very broad uniform magnetic surface would exhibit locally positive or negative anomalies (Breiner, 1973). Magnetic anomalies tend to be highly variable in shape and amplitude. They are generally asymmetrical in nature due to the combined affects from several sources. To complicate matters further, a given anomaly may be produced from an infinite number of possible sources. The distance between the magnetometer sensors and the magnetic source material also affect the shape of the apparent anomaly (Breiner, 1973). As the distance between the magnetic sensor on the magnetometer and the source material increases, the expression of the anomaly becomes broader. Anomaly shape and amplitude are also affected by the relative amounts of permanent and induced magnetization, the direction of the magnetic field, and the amount of magnetic minerals (e.g., magnetite) present in the source compared to the adjacent soil matrix. The shape (e.g., narrow or broad) and orientation of the source material also affects the anomaly signature. Anomalies are often identified in terms of various arrays of dipoles or monopoles (Breiner, 1973). A magnetic object in made of magnetic poles (North or positive and South or negative). A simple dipole anomaly contains the pair of opposite poles that relatively close together. A monopole anomaly is simply one end of a dipole anomaly and may be either positive or negative depending on the orientation of the object. The other end is too far away to have an affect on the magnetic field.

Analyses of the magnetic data from the fluxgate gradiometer survey indicated the presence of numerous magnetic anomalies within the Buildings Geophysical Project Area (Figure 13). The fluxgate gradiometer data were collected over the entire geophysical project area. The magnetic anomalies appear to be associated with ferrous metal objects, buried historic archaeological features, as well as modern ferrous metal intrusions. A cluster of extremely strong magnetic anomalies are located between N4980/E990 and N4995/E5015. This rectangular area was identified in the metal detector survey as a possible blacksmith shop location, which is located on the south side of a major trail swale through the pony express station location. The north side of the swale contains two clusters of magnetic anomalies. Within the larger area, there are three concentrations that may represent building locations associated with the station operations. Artifacts identified during the metal detector survey indicate that this area was the focus of domestic activities. Within the Swales Geophysical Project area, several dipole anomalies appear to represent isolated ferrous objects (Figure 14). The swales appear as weak linear magnetic anomalies with slightly higher magnetic values on the sides or edges of the swales. The ferrous objects may be objects fallen from wagons traveling along the overland trail or items lost from agricultural equipment post-dating the trail activities.

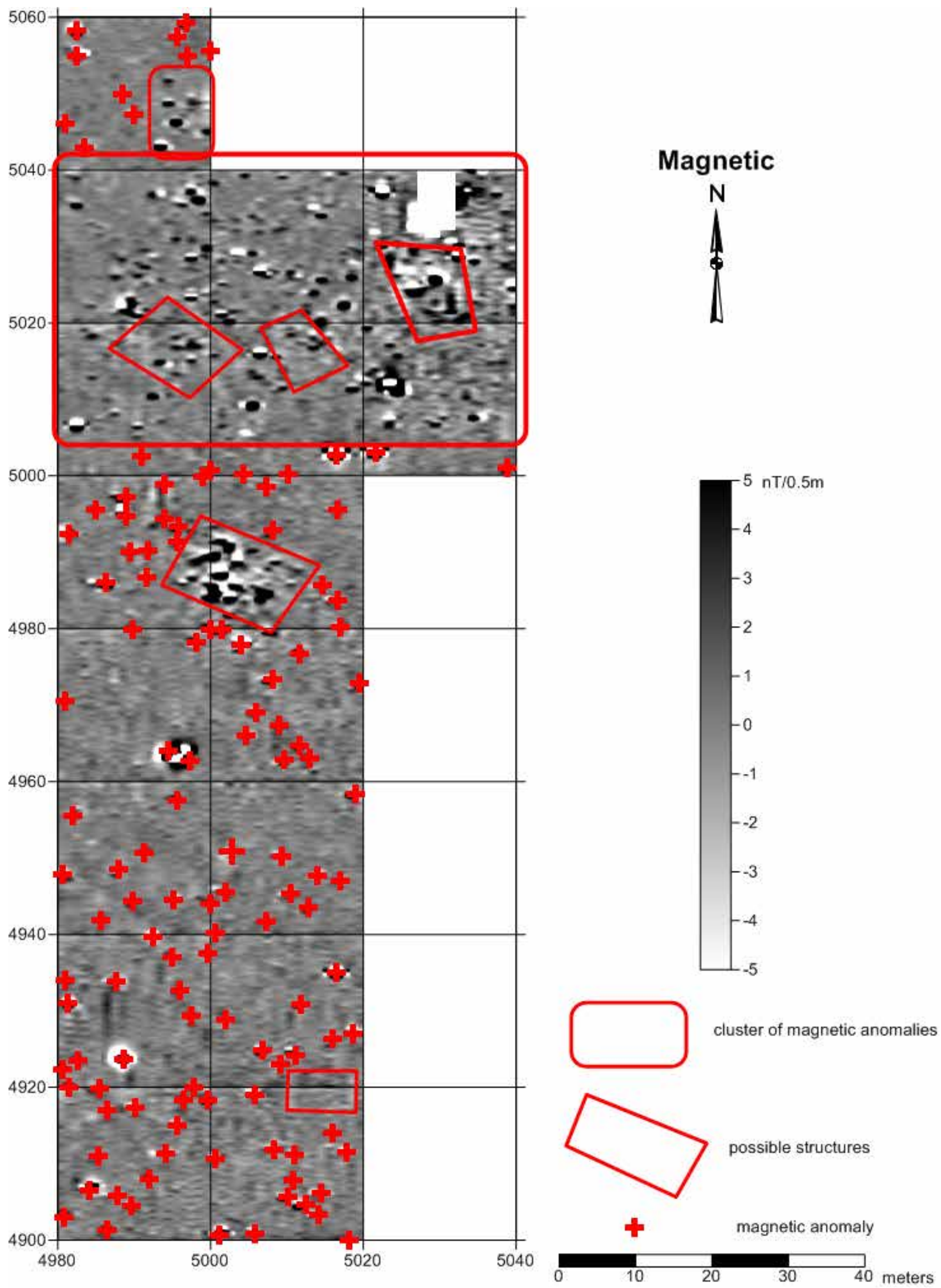

Figure 13: Interpretation of the magnetic data from the Buildings Geophysical Project Area.

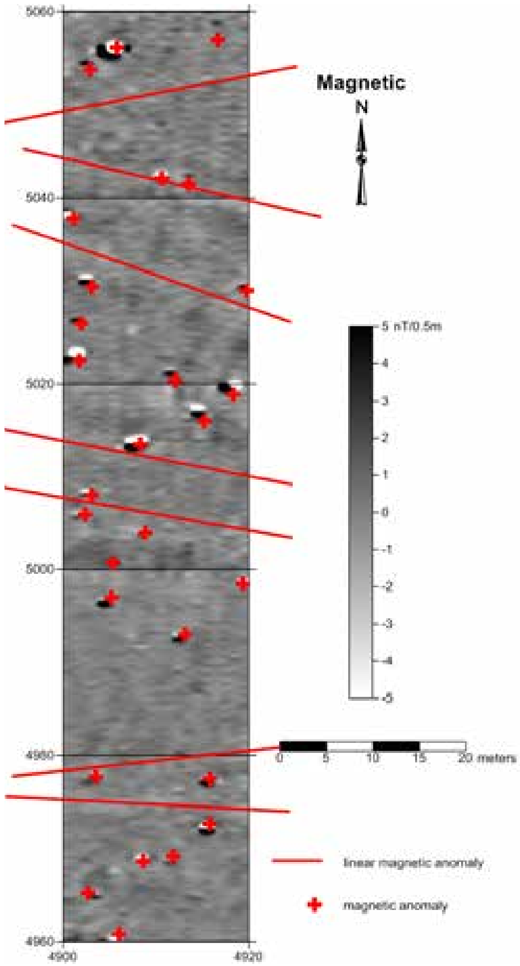

Figure 14: Interpretation of the magnetic data from the Swales Geophysical Project Area.

Interpreting the Resistance Data

Interpretation of the resistivity data results in the identification of lateral changes in the soil. Since the array parameters are kept constant through out the survey, the resulting resistance values varies with changes in the subsurface sediments/soil matrix and buried archaeological resources. For each probe separation, the depth penetration is approximately the same as the distance between the current and potential probe on the mobile array frame, which was 0.5 meters. The resistance measurement for each point represents the average value for the hemispheric volume of soil with the same radius. If the soil below the survey area was uniform, the resistivity would be constant throughout the area. Changes in soil characteristics (e.g., texture, structure, moisture, compactness, etc.) and the composition of archaeological features result in differences in the resistances across the surveyed grid. Large general trends reflect changes in the site's geology whereas small changes may reflect archaeological features. An advantage to the resistance survey and its interpretation is its usefulness in areas that have high concentrations of metal objects. Areas where erosion has removed the topsoil are represented by mottled coloration associated with extremes in weak and strong conductivity values.

The resistance survey of the Buildings Geophysical Project Area covered a 40-m by 40-m block within the entire area (Figure 15). The area identified as the blacksmith shop is identified as a rectangular high resistive area in the south central part of the grid. It measures approximately 11 meters by 8 meters. Two swale segments appear as low linear resistive anomalies on the north side of the blacksmith shop area. Several linear resistance anomalies are present in the Swales Geophysical Project Area (Figure 16). They consist of low resistive value anomalies between the higher resistive swells between the swales.

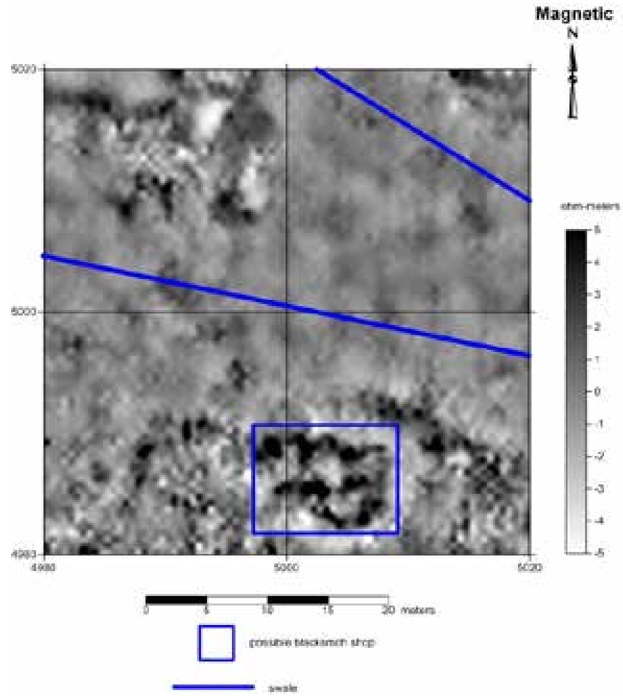

Figure 15: Interpretation of the resistivity data from the Buildings Geophysical Project Area.

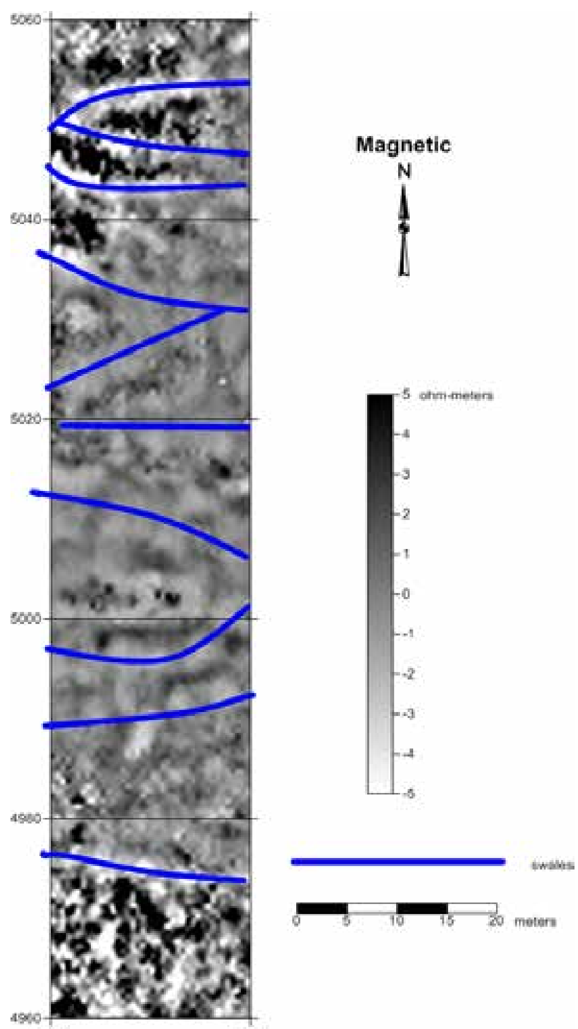

Figure 16: Interpretation of the resistivity data from the Swales Geophysical Project Area.

Combined Geophysical Data Set Interpretations

A different way of looking at the geophysical data collected during the investigations of the pony express station and trail swales at the Cold Springs Station site is to overlay the geophysical data on the 3D LiDAR hill shade composite (Figure 17). A number of the different geophysical anomalies overlap suggesting a strong correlation between the geophysical data and the buried archaeological features (Kvamme, 2007). These areas of overlap would be considered areas of high probability for ground truthing and the investigations of buried archaeological resources. While these correlations are important, individual isolated occurrences also need ground truthing in order to determine their unique nature as well. Complementary data (Clay, 2001; Kvamme et al., 2006) from the geophysical survey efforts at the site suggest locations of the 1860-1861 pony express relay station and associated buildings and for the overland trail swales of the overlapping 19th century overland Pony Express, California, and Oregon National Historic Trails.

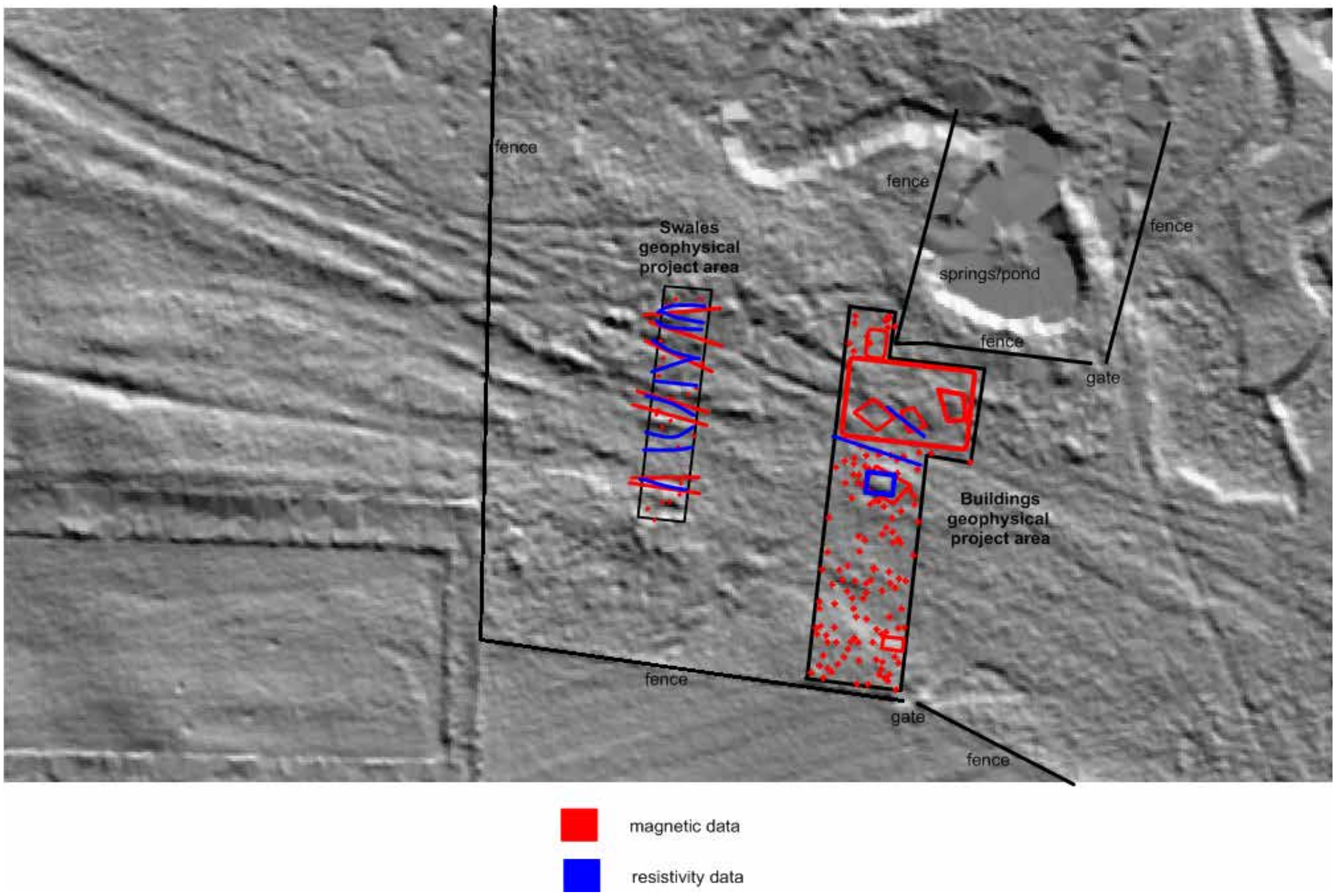

Figure 17: Combined geophysical anomalies from the geophysical project areas on the hill shade view of the Cold Springs Station site.

Conclusions

During August 2014, the Midwest Archeological Center staff conducted geophysical investigations at the Cold Spring Station site in Lincoln County, Nebraska. The geophysical investigations were conducted to provide information concerning the buried archaeological resources associated with the Pony Express relay station and the Oregon/Pony Express trail. The geophysical investigations included a magnetic survey with a fluxgate gradiometer and a resistance survey with a resistance meter and 4-parallel twin probe array. The resulting geophysical data indicated the location of the station's blacksmith shop and other structures associated with the station. The trail swales were also identified in the geophysical data.

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MULTI-SENSOR GEOPHYSICAL EXAMINATION OF THE HISTORIC DISTILLERY: BRENHAM, TEXAS

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Introduction

Brenham, Texas is a small town in Washington County located in east central Texas. Brenham is home to many historical sites that are important in the history of Texas. The site in question is owned by Blue Bell Creameries and is located on South Chappell Hill Street. An old distillery is believed to have been built on this site and may be the first of its kind in Texas. To accurately identify the location of the historic building, multiple geophysical methods were used. It is important to continue to search for any pieces of Brenham's diverse past in order to have a complete historical picture of the town. Brenham's central location between Houston, Austin, and San Antonio makes it a major hotspot for historical tourism in the state. Because of this, any historical findings could be significant to the town's economy.

Brief History of Brenham, TX

The town of Brenham was founded in 1844 when Texas was still a republic. The town was created by Washington County officials who needed a central hub to service a steep increase in population in the southwestern part of the county (Hasskal, 1933). Like many towns of the era, Brenham began as a small town with few residents and stores. Starting in 1860, Brenham began operating a small railroad to Hempstead, TX. The railroad expansion was mainly financed by J.D. Giddings who organized the Washington Railroad Company with his brother. In 1871, the line was extended to Houston and Austin. The town experienced continuing expansion of rail lines up until 1905 when the current station was constructed. During this time the town experienced rapid economic growth associated with the railroads and quickly became "one of the most important little cities in the interior of Texas" (Hasskal, 1933 p. 8). In fact, during the Civil War, Washington County's population exceeded that of Houston and Austin combined (Brass, 2011).

Keywords: Historic Distillery, Brenham - Texas, Magnetometry, Electromagnetic Induction, Ground Penetrating Radar.

The army post of Brenham Map No. 7 from 1868 represents one of the defining moments in Brenham's past (Figure 1). During the Reconstruction period following the Civil War, Company E of the Seventeenth Infantry's Third Battalion was sent to Brenham in 1865 led by Brevet Major George W. Smith. The camp was constructed east of downtown and quickly came to be called "Camptown" which has previously been geophysicaly examined (Meehan et al. 2015, this issue). The Soldiers presence caused many problems, eventually resulting in a large fire started by the soldiers that engulfed most of the town (Brass, 2011). The map is one of the only references to the location of the distillery. While the general location of the distillery can be determined, the map has several scale issues commonly seen in historic maps.

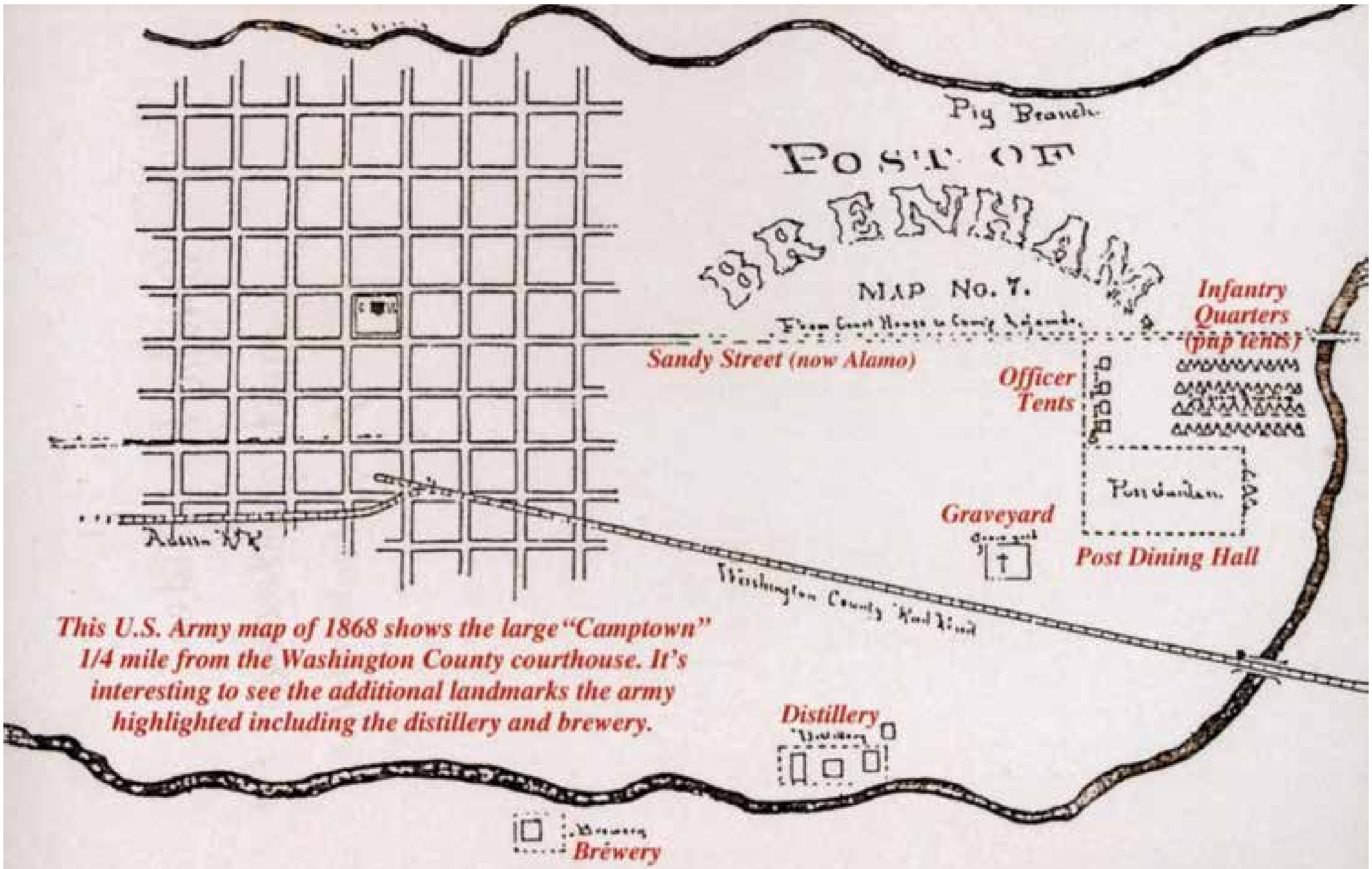

Figure 1: Army post of Brenham Map No. 7 depicting the location of historic "Camptown" and general location of the distillery from Brass (2011).

Property information

The geophysical study focused on the property located at 507 South Chappell Hill St., Brenham, TX 77833. The Washington County Appraisal District identification number is R42537 and is owned by Blue Bell Creameries, LP (W.C.A.D., 2014). The site has been utilized for several uses in the past decade, including a recreational baseball field in the northern portion of the property. The property also has several small municipal water buildings. The main geophysical interest in the property is in the southern portion near a creek which acts as one of the properties borders. In this area is believed to be the location of one of the first distilleries in Texas. An aerial of the site is shown with the location of the survey area in red (Figure 2). A portion of the army post map has been georectified onto the aerial map to show the putative location of the distillery (Figure 3). Because the army post map suffers from spatial inaccuracy like many historic maps, the location of the buildings should be considered as a hypothesis to test with geophysical techniques.

Figure 2: Aerial photo of the property with location of the geophysical survey is shown in red.

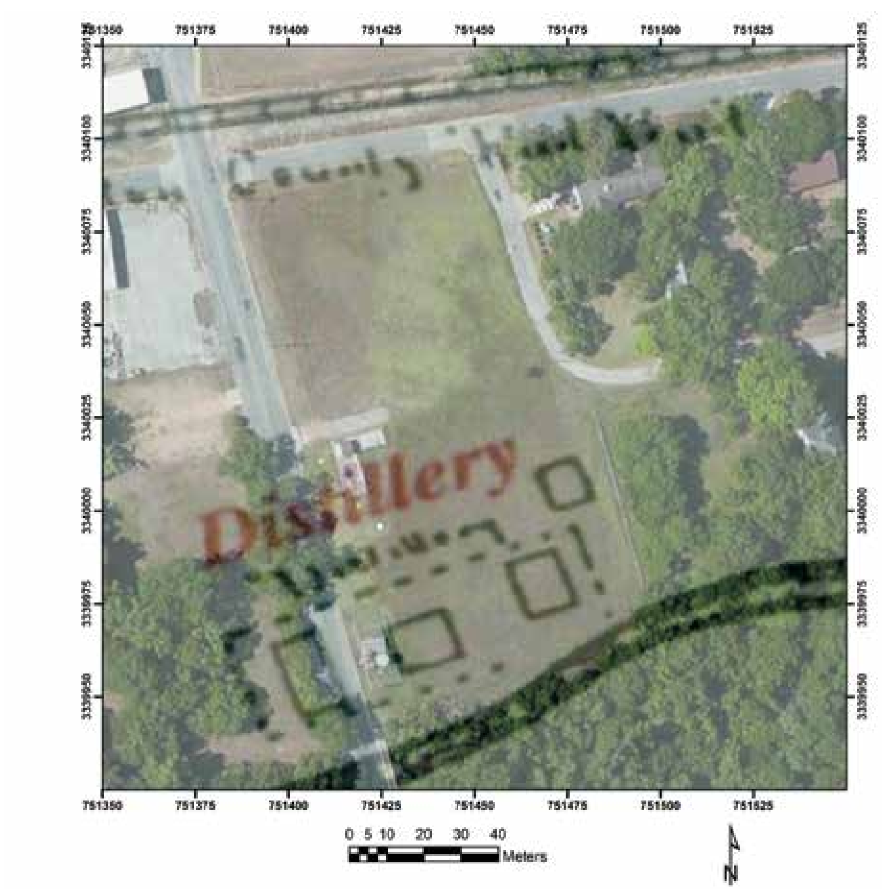

Figure 3: Georectification of army post map onto aerial photo.

Project Objective

The ultimate objective of the project was to map the location of the unknown structure of the distillery. In order to accomplish this, multiple geophysical techniques were used. The magnetometer allowed the detection of magnetic objects in the sub-surface. Electromagnetic induction measured any relative apparent elctrical conductivity changes in the soil commonly associated with metallic or non-conductive objects such as building foundations. Ground-penetrating radar recorded any relative dielectric permeability contrasts in the subsurface detecting a wide array of sub-surface objects. Each of these techniques has drawbacks when used separately (Clay, 2001), but when combined and correlated, these three measurements provided a more complete picture of any objects present in the sub-surface. Both qualitative and quantitative methods were examined to effectively combine the results of multiple geophysical sensors. The majority of the results presented were completed for an undergraduate thesis by Charles Stanford (Stanford, 2015).

Methods

Survey Grid Construction

The sub-surface mapping of the project location was completed using three geophysical techniques: magnetrometry (MAG), electromagnetic induction (EMI), and ground-penetrating radar (GPR). To tie all three geophysical techniques together, a common site grid was established in the southern area of the property. Care was taken to keep the grid as far away as possible from the municipal water buildings located near Chappell Hill St. Care was taken to minimize the effect of magnetic and electromagnetic properties of the buildings during data acquisition. Other restrictions on the survey area were a sharply dipping creek bank on the southern border of the property, and a chain link fence on the eastern edge of the property.

A 40 x 40 meter Cartesian coordinate system grid was constructed. The origin point (0,0) of the grid was placed in the south-east corner. Blaze orange non-magnetic surveyor spikes were used to permanently mark the corners of the grid so that in the future, geophysical surveys could be repeated in the same location

Magnetometry

The primary purpose of conducting a magnetometer survey was to detect any iron bearing artifacts associated with building structures (Everett 2013). The G-858 Cesium Vapor Magnetometer was used in vertical gradiometer mode. A specialized magnetometer cart was constructed in order to keep the sensor heights constant at 0.4 and 0.9 meters during the survey (Figure 4). Data was collected continuously at 0.5 meter line spacing with 5 meter fiducial lines, with a sampling rate of 0.1 seconds or 10Hz.

Electromagnetic Induction

The primary purpose of EMI was the ability to measure changes in electrical conductivity in the subsurface. Metallic objects give high or negative apparent conductivity, while objects such as bricks and foundations give low apparent conductivity measurements (Everett, 2013). To complete the electromagnetic induction survey a terrain conductivity meter, the GSSI EMP-400 Profiler, was used. During the survey, the Profiler was used in “In-Line” mode where the Profiler is parallel to the direction of travel. The Profiler was carried 0.15 meters above the ground, transmitted an 8 kHz signal, and sampled data every 0.25 seconds. The EMI survey also used 0.5 meter line spacing with 5 meter fiducials.

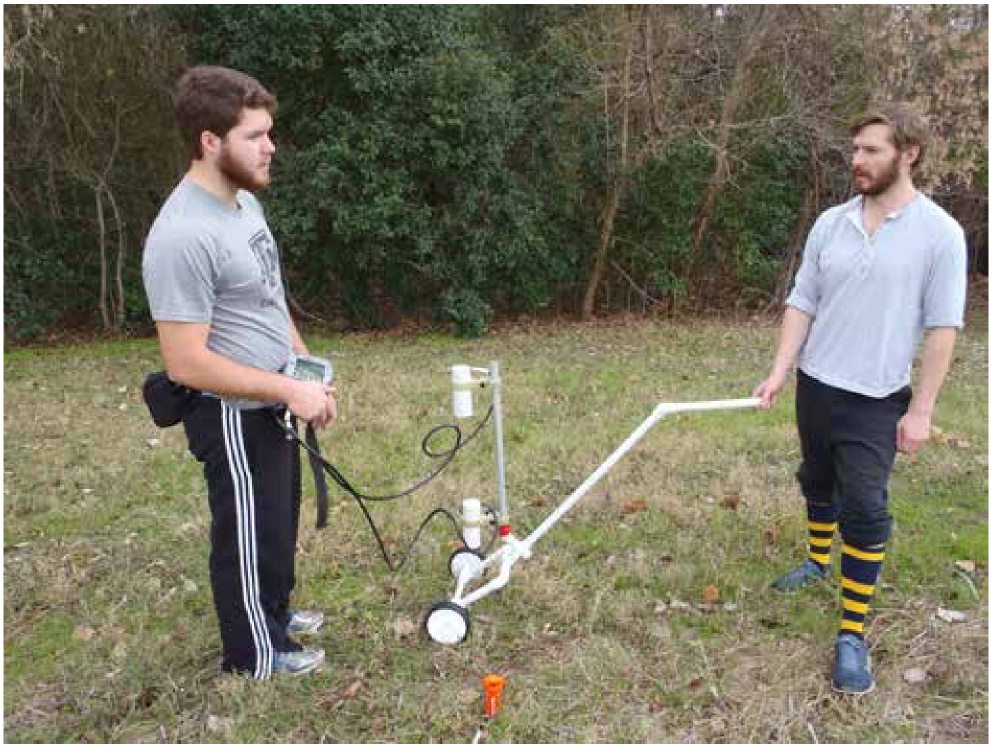

Figure 4: Prototype Magnetometer Cart Operated by Charles Stanford and Tim de Smet.

Ground-Penetrating Radar

The primary purpose of GPR was to measure any relative dielectric permeability contrasts in the sub-surface. These contrasts allow the detection of many types of sub-surface objects. To complete the GPR survey, a Sensors and Software PulseEkko Pro GPR system was used with 500 MHz antennae. The GPR survey was conducted with 0.25 meter line spacing and trace spacing of 2 cm with a calibrated survey wheel odometer. Several GPR studies completed in the area have found that high clay content of the soil causes poor results unless there was low moisture content in the sub-surface (Meehan, 2014). Due to the poor soil and weather conditions, the GPR survey was not conducted over the full 40 x 40 meter grid. Instead two sub-grids were used. Sub-grid A measured 20x20 meters, and was located over an area of high anomaly density seen in both the MAG and EMI surveys. Sub-grid B measured 5 x 5 meters and was located over an isolated anomaly that was used for examining correlation techniques.

Hilbert Transform

The Hilbert Transform (HT) is commonly used in complex trace analysis of seismic and GPR data. The HT uses the real trace to compute the quadrature or imaginary trace. From the quadrature trace, several diagnostic values can be calculated (Tanner, 1979). The HT can also be used for different types of geophysical data. The absolute value of the HT was used in order to remove the dipole behavior of MAG and EMI anomalies (Young, 2004).

The nature of MAG and EMI anomalies are inherently different. MAG anomalies are typically represented by an increase then decrease in magnetic field magnitude referred to as a dipole. EMI anomalies typically exhibit only a decrease or only an increase in magnitude referred to as positive or negative monopoles (Figure 5a). Even though qualitatively it can be seen that the MAG dipole and EMI monopole are in similar locations, quantitatively it is hard to determine that they are in similar locations. The standardized HT results of the MAG and EMI transects show both anomalies have been converted to positive monopoles, and are both qualitatively and quantitatively seen to be in similar locations (Figure 5b).

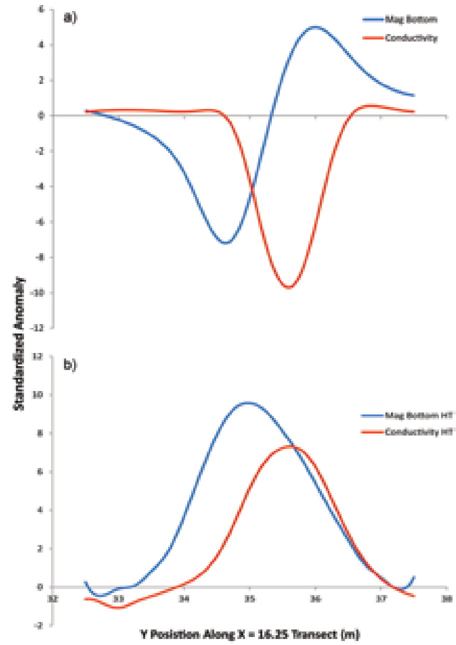

Figure 5: Example of Hilbert Transform on MAG and EMI data from sub-grid B.

Results

Both EMI and MAG data were processed with the MATLAB processing suite GeopMapper (Stanford, 2015). GeopMapper includes various filters such as de-spiking, even grid interpolation, weighted average smoothing, and median line de-stagger. GPR processing included background subtraction, bandpass filtering, gain, migration at .077 m/ns, and calculation of the Instantaneous amplitude. The data were processed using EKKO_Project 2 and MATLAB R2015a.

Magnetometry

Processed results of the magnetic gradiometer data is shown in Figure 6. The presence of both large and small anomalies can be seen in the survey area. Some of the larger anomalies have magnetic gradients upwards of 1000 nanoTeslas per meter (nT/m), while some of the smaller anomalies have gradients of approximately 100 nT/m. The large variety of anomaly sizes represents a large variety of iron bearing artifacts in the sub-surface.

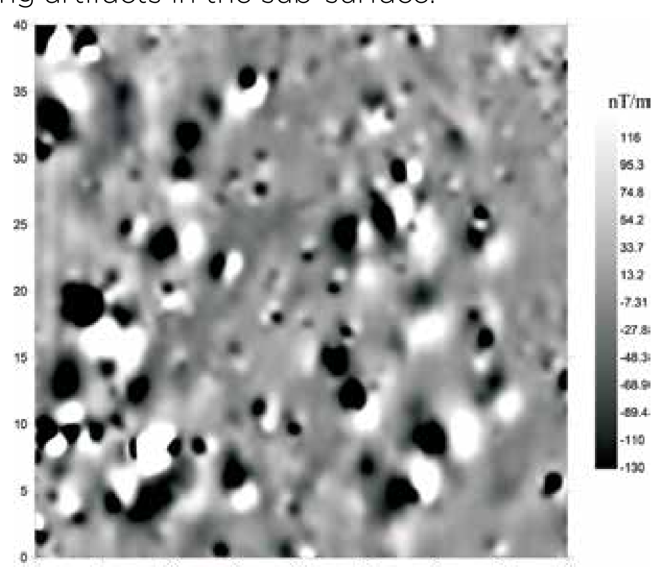

Figure 6: Magnetic gradiometer results.

Electromagnetic Induction

Processed results of EMI apparent conductivity data in milliSeimens per meter (mS/m) is shown in Figure 7. Red anomalies correspond to negative apparent conductivities and represent metallic objects. While metallic objects should have a higher conductivity than the surrounding soil the metallic nature of the artifacts causes the LIN approximation used in electromagnetics to break down, allowing the apparent conductivities to be negative. There are also several anomalies that are not quite negative but have very low conductivities approaching 0 mS/m, which also represent metallic objects. The survey area also contains anomalies that have a lower conductivity than the surrounding soil but do not approach 0 mS/m. These anomalies have minimums of approximately 50 mS/m and represent non-conductive materials such as bricks or building foundations. The in-phase results in parts per million (ppm) are shown in Figure 8. In-phase data relates to the magnetic susceptibility and metallic content of the sub-surface. There are several large anomalies in the in-phase data. Many of these correspond to the negative and near negative anomalies in the apparent conductivity results, solidifying the interpretation of metallic objects in the sub-surface at those locations. Also, low conductivity anomalies representing non-conductive objects do not necessarily have corresponding strong in-phase anomalies, confirming the possibility of non-conductive objects in the sub-surface.

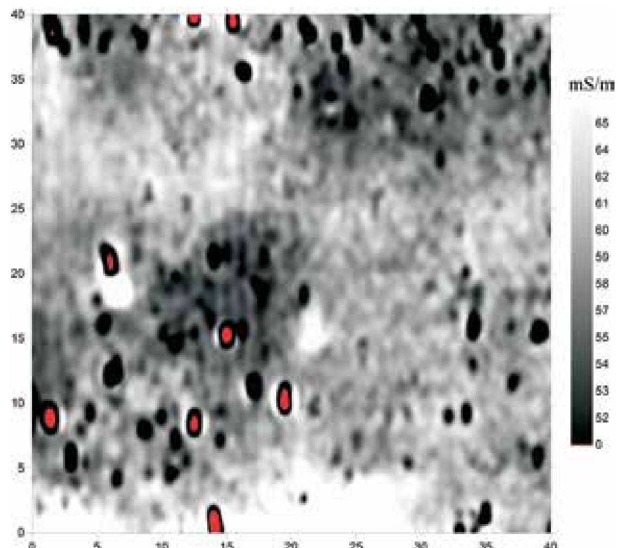

Figure 7: EMI apparent electrical conductivity (8kHz).

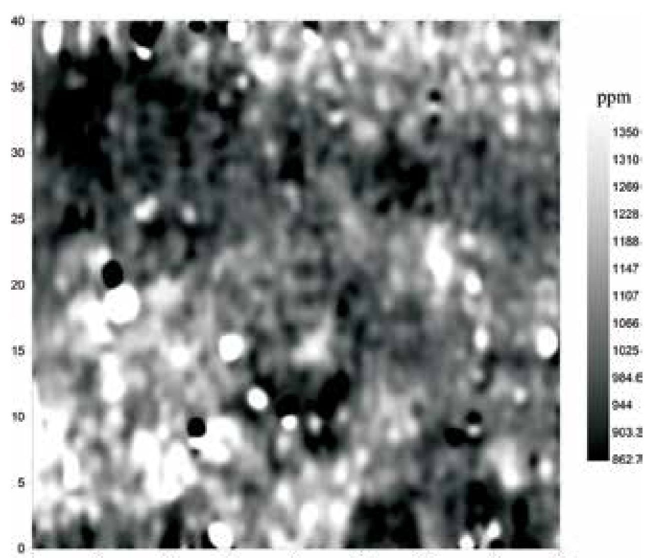

Figure 8: EMI in-phase (8kHz).

Ground-Penetrating Radar

GPR Instantaneous Amplitude depth slice from 5 to 10 cm shows the locations of reflectors in the sub-surface (Figure 9). There are many large reflectors seen in sub-grid A and a few small reflectors in sub-grid B. In sub-grid A, some of the reflectors form a linear structure in the sub-surface possibly representing the foundation walls one of the buildings of the distillery.

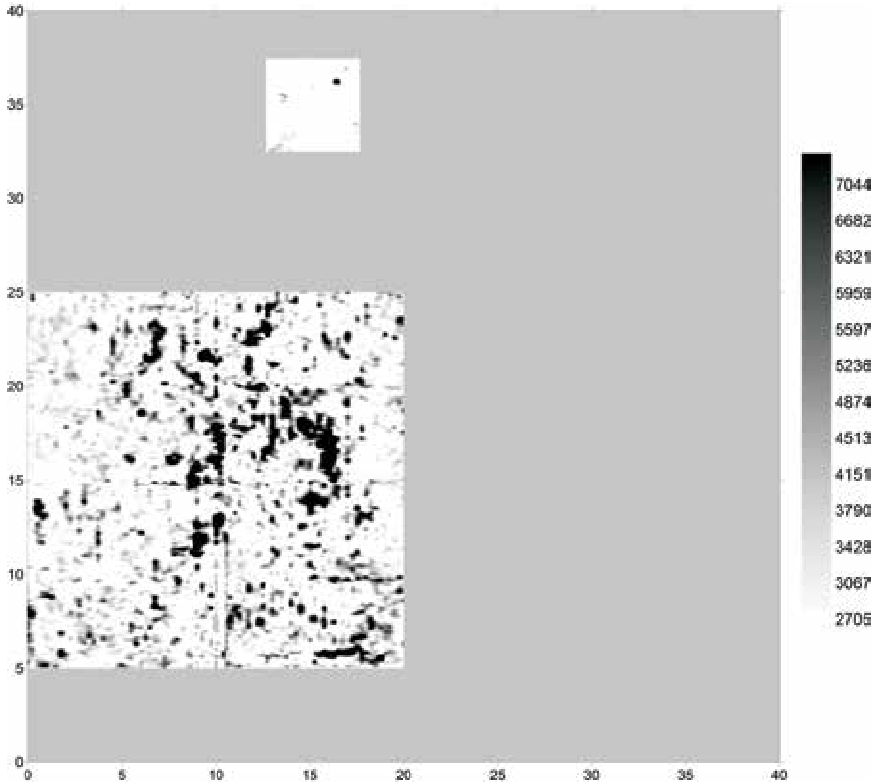

Figure 9: GPR instantaneous amplitude depth slice (5-10 cm).

Analysis

To better understand the results from the different geophysical techniques, both qualitative and quantitative analysis were used. Qualitative analysis was accomplished by anomaly overlay analysis, where the results of one method are depicted over the results of another method. Quantitative analysis was accomplished through standardization thresholding of Hilbert Transformed data.

Qualitative Analysis

Overlay analysis allows subjective visual correlation of different geophysical methods. EMI anomalies in yellow are shown over the background MAG bottom sensor in gray (Figure 10). There were several EMI anomalies that visually correlated with MAG anomalies, especially in the lower left area of the survey. This was expected as MAG detects anomalies from objects containing Iron-Titanium oxides (Fe-Ti) and EMI can detect anomalies from all metals that produce secondary magnetic fields. Interestingly there was a large area where there was a high density of MAG anomalies, but none in the EMI data. GPR depth slice from 5-10 cm in red is shown over EMI conductivity in gray (Figure 11). The anomaly in sub-grid B is seen in both GPR and EMI. In sub-grid A, GPR anomalies correspond much better to EMI anomalies than MAG did. This can be attributed to EMI's ability to detect a wider array of objects than MAG. The main GPR structure is also seen in EMI as a general decrease in conductivity in the same area.

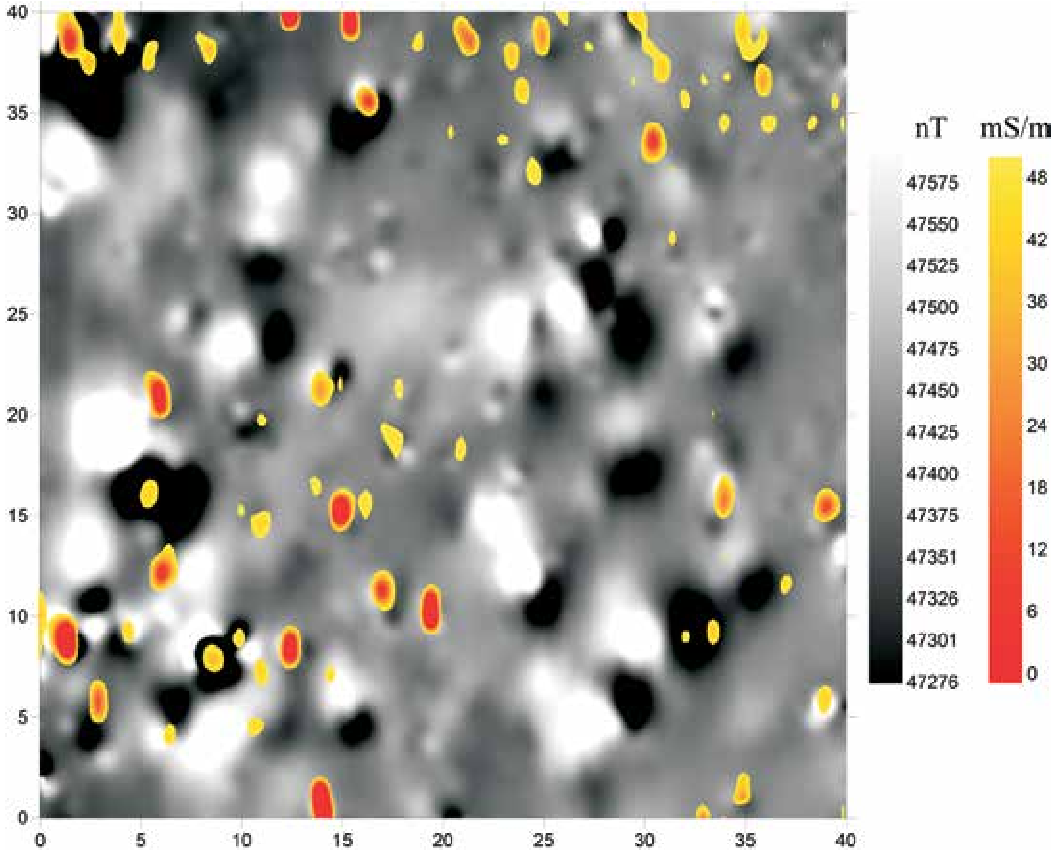

Figure 10: EMI electrical conductivity over MAG bottom sensor.

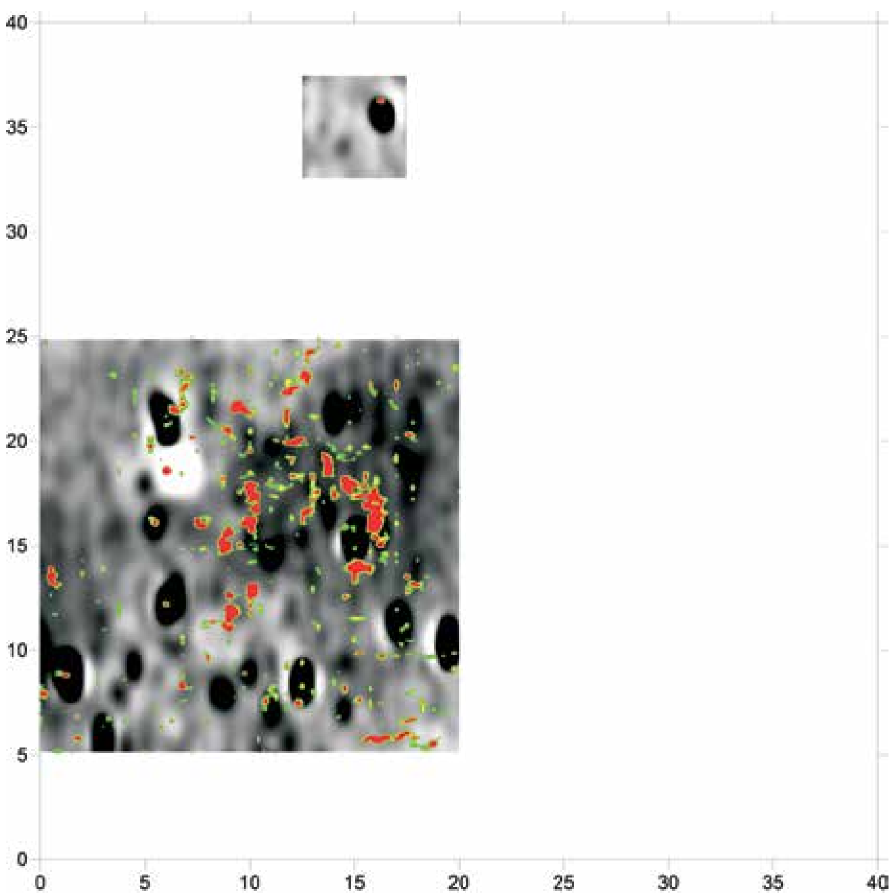

Figure 11: GPR instantaneous amplitude over EMI electrical conductivity.

Quantitative Analysis

Standardization thresholding was used on 2-D Hilbert Transformed MAG and EMI data to quantitatively analyze the data. An in-depth discussion and depiction of the 2-D Hilbert Transform on this data set can be found in Stanford (2015). A threshold of two standard deviations from the mean field was set to determine the location of anomalies. For a certain location to have correlated between different methods, it had to meet multiple threshold requirements. For example, if a data point met the requirements for a MAG anomaly but not an EMI anomaly the point would be represented as only a MAG anomaly. If the data point met the requirements for both MAG and EMI anomalies, the point would represent a correlated MAG and EMI anomaly. The full grid results of standardization thresholding for MAG and EMI show locations with no anomaly in grey, MAG only anomalies in blue, EMI only anomalies in yellow, and correlated anomalies in red (Figure 12). The area which is conducive for further archaeologic investigation has been boxed on this plot. There are several locations where MAG and EMI anomalies correlate very well, but again, the right side of the grid sees MAG anomalies not associated with EMI anomalies.

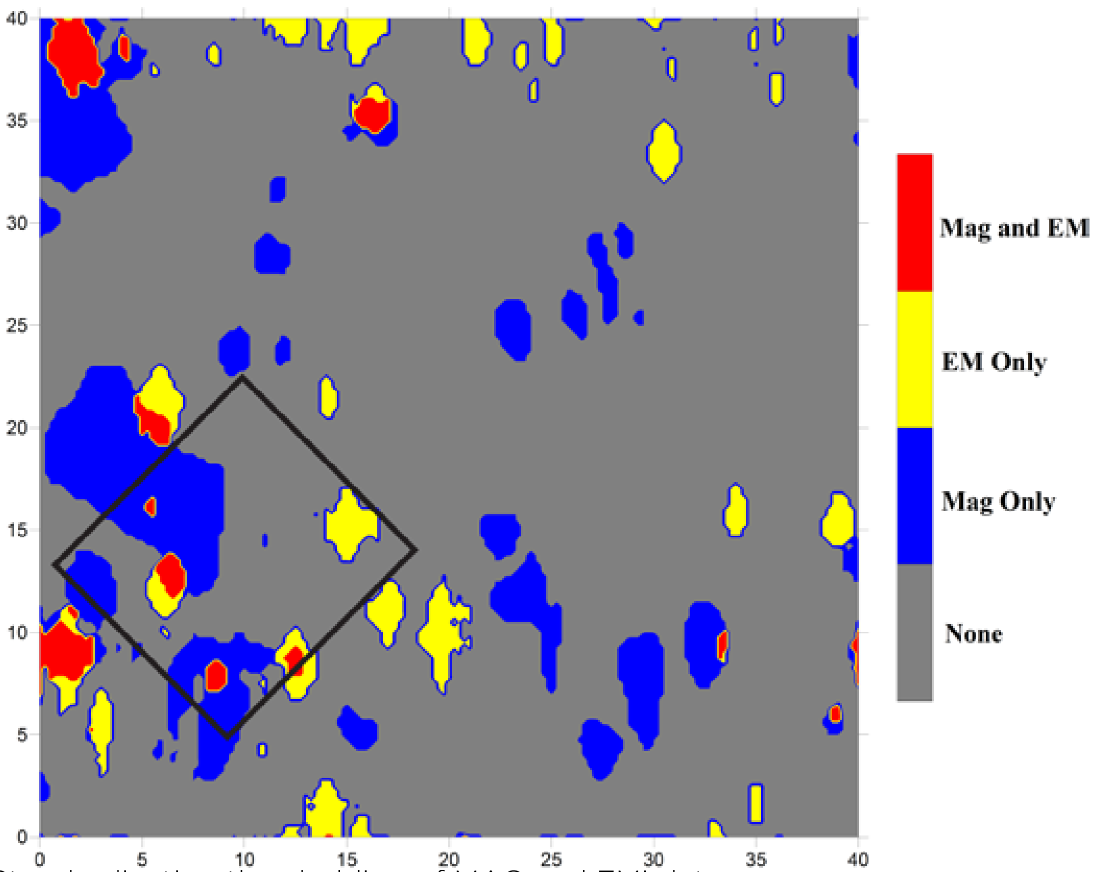

Figure 12: Standardization thresholding of MAG and EMI data.

Conclusions

Ultimately, the project objectives were met. An unknown sub-surface structure was located using a variety of geophysical methods. Each technique yielded significant results on its own. It was only when all three of the geophysical sensors were utilized that the complete picture of the sub-surface was revealed. The MAG survey showed that the field contains many sub-surface artifacts containing Fe-Ti oxides of various sizes. The EMI survey showed both metallic and non-conductive objects in the field. The GPR survey showed a large amount of sub-surface reflectors that could be caused by a wide array of artifacts. GPR allowed more precise locations of anomalies to be determined.

Qualitative vs. Quantitative Analysis

In order to visualize data from multiple geophysical methods, both qualitative and quantitative analysis were used. To quantitatively analyze the data, standardization thresholding was used to enhance major anomalies and suppress smaller anomalies. While this was effective at simplifying the results, there was a certain loss of information associated with the process. In the future, other methods of quantitative analysis should be examined that preserve more information. Qualitative overlay analysis was extremely effective at visualizing different geophysical methods. Both large and small anomalies were preserved and visualized. Ideally, both methods of analysis should be used to completely understand the data. Overlay analysis has the ability to stand alone as an analysis technique, while magnitude thresholding does not.

Historical Significance

Our interpretation cites this distillery to be evident: considering georectification of historic maps accompanied with a geophysical approach. Three geophysical methods each revealed substantial anomalies in the subsurface. And based upon the extant of magnetic, electromagnetic and radar artifacts, we have defined a boundary of which further archaeological investigation may be initiated. Many anomalies were consistent throughout multiple techniques, and a boundary has been defined for future discovery. In order to prove the existence of structures in the sub-surface, archeological excavation of the site is recommended. The data from the three geophysical methods indicates that the survey should focus on the areas in sub-grids A and B. Once the archeological survey is completed, final conclusions about the site will be made.

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MERGING CULTURES & CURRICULUMS: ENRICHING HERITAGE AND EDUCATION WITH APPLIED GEOPHYSICS

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Abstract

The Camptown African American Cemetery is analogous to many unexplored heritage cemeteries throughout the southern United States. It is a challenging site both culturally and physically. Our study caters to many facets of learning by delving into the history of the birthplace of Texas and merging physical science with social science. The study allows the opportunity to enrich the colligate curriculum with practical teaching of these sciences. This site also serves as a proving ground for the advancement of archaeological methodology with applied geophysics. The practice of our methodology devises a multi-component approach, which provides the greatest achievable insight of the cemetery. A high precision topographic (TOPO) magnetic (MAG) and electromagnetic induction (EMI) survey was best tailored for the terrain of the cemetery. Ground coupled or towed sensors, like many radar systems, are inoperable in field conditions as these. Processing techniques were developed to integrate the data sets. The MATLAB processing suite GEOPMAPPER, developed by Stanford et al. (2015: this volume), manipulates the acquired data from its raw form into a polished product. Interpreting the results presents the greatest challenge. The community of Brenham, Texas has the expectation that remains of their ancestors will be apparent in the geophysical work. This is impossible knowing the limitations of hard science. Our best attempt draws the position on the map where the combination of the multi-component research indicates the visual and statistical probability of a marked or anonymous burial. Ambiguity in the interpretation will exist in a site cluttered with coherent and incoherent noise. And this is our best attempt to provide a qualitative and quantitative mapping of the Camptown Cemetery. This paper also delivers a provocative awareness of the State of Texas at a time of dynamic cultural change. We want to call attention to the period and place of this anthropogenic cause; its history and heritage on a human level, aside from the geophysical work.

Keywords: Camptown African American Cemetery, Brenham - Texas, Topographic Survey, Magnetometry, Electromagnetic Induction.

Introduction

It is amazing and fortunate that anthropologists, namely ethnographers, working for the Works Progress Administration (WPA) in the 1930s were able to interview and transcribe what life was like in Texas during the horrors of slavery (Tyler and Murphy, 1997). The interviewees were often very young before and during the Civil War and quite old in the 1930s; however, their recollections and memories of the time were incredibly vivid. Their accounts speak to the inhumanity of slavery and the deep human yearning for freedom, a quintessential American theme. Slaves in the area of Brenham, Washington County, Texas often took refuge in the densely wooded forest near the Hog Branch Creek (Figure 1). The woods offered cover to hide, but also natural resources like timber and water to survive. After the Juneteenth Emancipation on June 19, 1865, the former slaves of Brenham chose to build a community on the creek as free citizens in the area they once escaped to find fleeting moments of freedom.

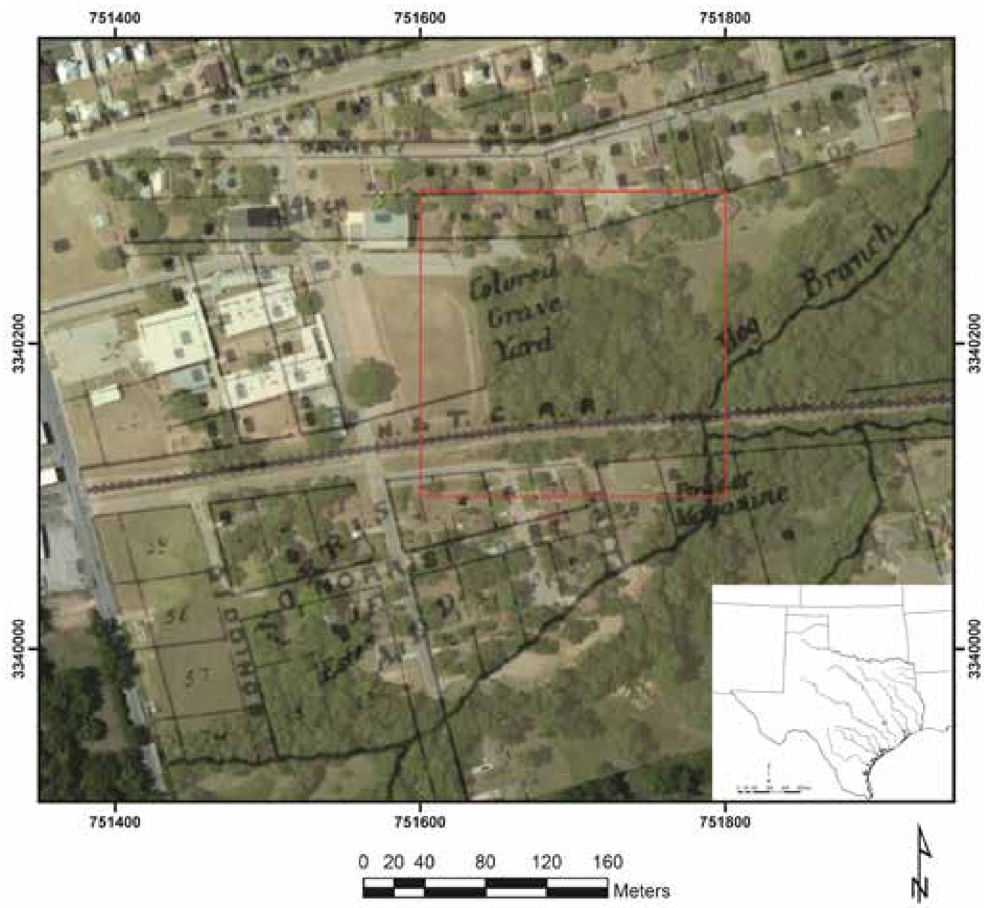

Figure 1: Georectified historic map overlain on modern aerial. Location of Brenham within Texas marked with red dot on inset map. Red square notes subarea shown in Figure 2. Note the historic map shows the location of the "Colored Grave Yard" and Hog Branch Creek described in the text.

A Brief History of the African American Community in Brenham, Texas

Between 1836 when Texas gained independence from Mexico, where slavery was illegal, and the 1860 census the population of the state rapidly grew from under 40,000 to over 600,000 – a greater than 1400% increase in just under 25 years! Of these immigrants three-quarters were from the southern United States, where slavery was still legal, and 182,566 were African American slaves (Campell, 2003; Campbell 1993). In 1860 Washington County was the second largest slave owning county in Texas with a total of 7,941 slaves (Stephens and Zuber-Mallison, 2010). After Abraham Lincoln's election in 1860, southern states began to join the secession movement. Three states even held popular referenda to vote on the matter: Virginia, Tennessee, and Texas. In Texas, white male citizens voted on whether or not to secede from the Union and a statewide special referendum was held on February 23, 1861. The measure passed with 75.66% of the vote in the entire state and an even more overwhelming 96.3% in Washington County (Stephens and Zuber-Mallison, 2010). Suffice it to say, slavery was popular and supported by white males in Washington County prior to the American Civil War. This is the socio-political context in which the Camptown African American community and cemetery were founded.

The years following the Civil War were a time of dynamic cultural change in Brenham, as the freed former slaves of Washington County greatly outnumbered the white population (Brass, 2011). During Reconstruction there was violent conflict between whites and the recently emancipated African American community; conflict which all too often took the form of mob violence and public lynching (Carrigan, 2006). Because of the violent unrest, the United States sent Company E of the Seventeenth's Third Battalion to Brenham in July of 1865 to maintain peace and protect the African American community from retaliation by angry whites (Harrison, 2009). The Federal Army made their camp along the Hog Branch Creek along with the flourishing African American community. As such, the local African American Cemetery – that is the focus of this paper – bears the name "Camptown" today, due to the Federal Army's presence there in the mid to late 1860s. The federal soldiers were stationed just one hundred meters northeast of the current graveyard at Camptown, from whence the cemetery derives its name (Figure 1).

Geophysical Surveys in Complex Environments

Unmarked graves are amongst the most difficult to detect and correctly classify of all common geophysical targets. Their geophysical response is often subtle and can be confounded by coherent noise like tree roots, headstones, iron railings, other cultural debris, and a wide variety of possible burial styles. Ground-penetrating radar is the most commonly used geophysical technique in historical cemetery surveys (Conyers, 2006); however, GPR like all geophysical techniques has known limitations, which can affect its potential, and these include but are not limited to terrain, above ground obstacles, vegetation, soil and sediment mineralogy, water saturated soils, rocky heterogeneous soils, subsurface metal debris, frequency interference, and many other complicating factors. We previously tested GPR at Camptown with multiple antenna frequencies but always with similarly poor results. The aforementioned obstacles proved too difficult for GPR in this complex environment. Instead, the flexibility and maneuverability of magnetometry and frequency-domain electromagnetic-induction proved much more capable for the task. No one method is perfect (Bevan, 1991; Davenport, 2001; Jones, 2008) and the use of multiple geophysical techniques is better than any single technique as they each have strengths and weaknesses (Clay, 2001), because they generally measure a different physical property of the subsurface (Everett, 2013). The use of multiple methods (Nobles, 1999) and spatial patterning (King et al., 1993) improves the confidence of predictions at cemetery sites. Bigman (2014) recently demonstrated the utility of GPR and EMI to detect unmarked slave burials at a cemetery in Georgia.

Unfortunately gravestones and burials are not always reliable indicators of burial location (Conyers, 2012; Fiedler et al., 2009) due to various cultural and natural processes. Cultural processes like migration, neglect, abandonment, vandalism, and the movement of headstones in conjunction with the physical processes of erosion, weathering, and decomposition of the ground and burial materials, among other factors, make it difficult to accept the location of headstones as an accurate indication of the subsurface in historic cemeteries. The Camptown Cemetery is no exception and is in fact analogous to many historic African American cemeteries in the southern United States, where anthropogenic and geological factors have dislocated cemetery markers. The cemetery fell into disrepair and was completely overgrown with vegetation (Figure 2a). Geophysical data sets are an excellent test of the accuracy of headstone location and extant of anonymous graves. Though, operating a survey amongst vines, tree stumps, iron fence posts, metallic litter, and undulating terrain introduces many challenges to the geophysical data acquisition and processing.

Figure 2: (a) Location of 20 x 20 m survey grids A-O and topography at 0.5 m contour interval. The topography slopes over 6 m through the survey area from west-to-east toward the Hog Branch Creek, as seen in Figure 1. (b) Through the enormous efforts of the community the once dense forest at the site (left) has been considerably thinned (right).

Data Acquisition and Standard Processing Methodology

Geophysical cemetery mappings should culminate in a finished product which displays the true presence of burials, marked or anonymous; however, in many cases the location remains unclear. Through the practice of graphical visualization and statistical methods we have provided two scopes through which the work may be interpreted. Efficiency in the field is adjoined to the acquisition and processing of high fidelity geophysical data. Topcon GT-313 Total Station, Geometrics G-858 Gradiometer and the GSSI EMP-400 Profiler were elected for the TOPO, MAG and EMI surveys respectively. Standard archeological survey parameters of 0.5 meter line spacing were implemented upon a survey area measuring 0.6 hectares. The control map is a Cartesian grid 60 meters in the x-direction and 100 meters in the y-direction. The field was sub-divided into 15 regular 20 meter by 20 meter grids (Figure 2a). The smaller grids were surveyed individually. Data handling throughout post-acquisition processing was much improved using this sub-grid method.

Ferrous and metallic litter within the cemetery was remediated through a user-defined computer process, as metallic debris take the form of localized signal noise in the pre-processed data. Standard processing techniques were used to filter the raw data: a spike and dropout routine, a median removal, and a smoothing low-pass kernel convolution (Figure 3). Algorithmic computation applied to the data construct removes the signal noise effects of loose metallic litter. Only the strong signals survive. These strongest signals are identified as anomalous targets. In the context of a graveyard we infer these targets to be cultural remains. However, filtering data may also reduce the appearance of cultural remains. For instance a deteriorated wooden casket may have only been visible in the geophysical data due to the presence of oxidized nails. The image becomes a semblance allowing for anthropogenic interpretations.

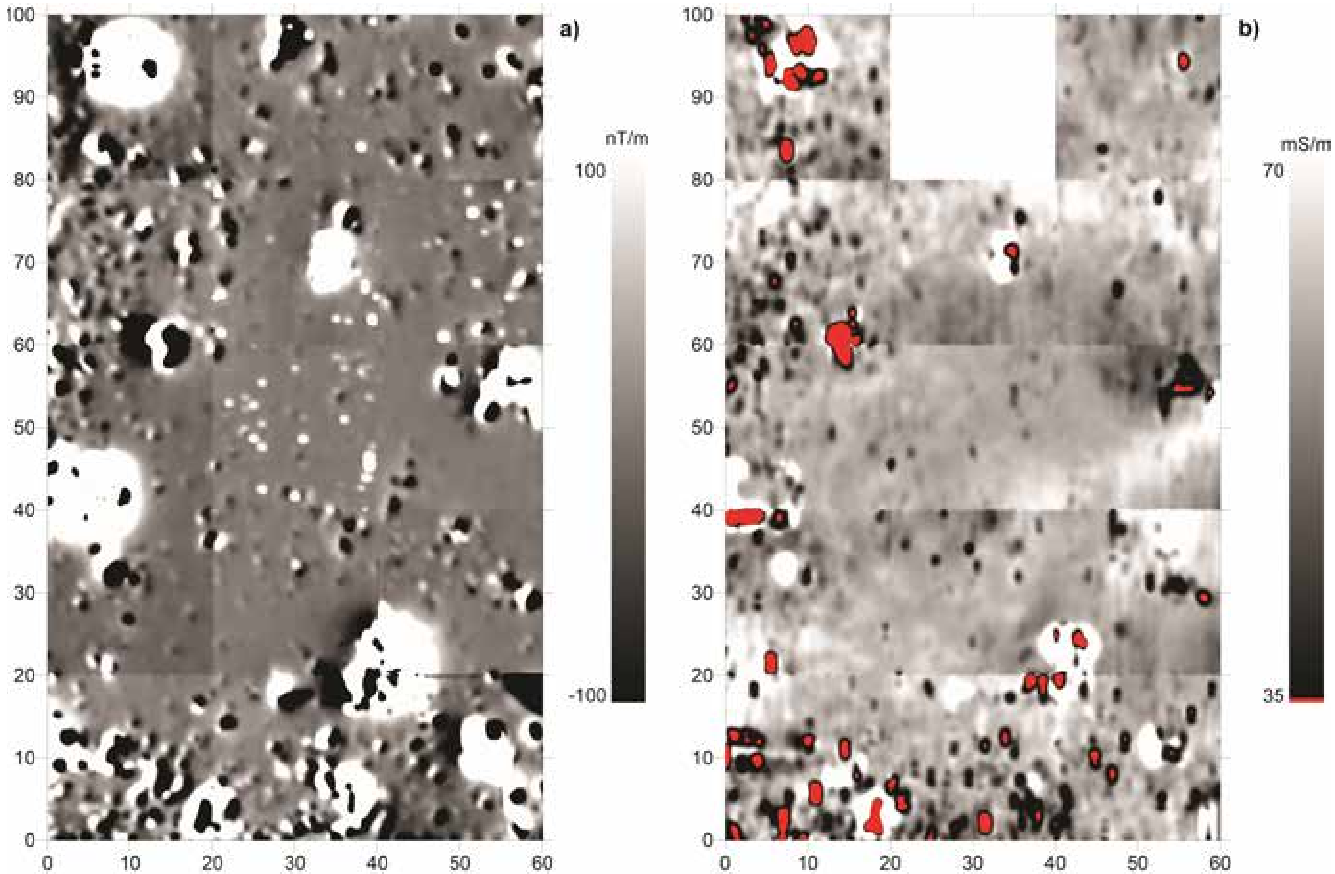

Figure 3: (a) Magnetic gradient in nT/m and (b) 8 kHz frequency-domain electromagnetic-induction data in mS/m. The negative apparent conductivity values have been colored red. The origin (0,0) is at the north west of Grid A and (60,100) is south east in Grid O as can be seen in Figure 2.

Improving Interpretations

A 2-D Hilbert Transform (HT) was applied to the MAG and EMI signals to boost the mathematical structure of the data (Young, 2004). Because the data construction now takes a bolstered form, an improved quantitative target analysis is possible. To delineate the extant of cultural remains within the Camptown Cemetery, the HT data of MAG and EMI targets was developed into a representative tool (Figure 4). This approach expresses location in a statistical sense. Statistical analysis improves prediction accuracy in EMI data (de Smet et al. 2012). The signal threshold of evaluation is measured at two standard deviations or greater against the field mean. In the locations of caskets or historic iron fence, strong response signals are detected by the instrumentation, which tend to fit the form of an analogous signal two standard deviations away. Any HT data below the threshold of evaluation have been reduced to the background, illuminating locations with statistical confidence.

A standard processing tool used to combine the information content of multi-sensor geophysical data is overlay analysis, where the target signal from one technique is overlain on another. Negative apparent conductivity EMI data has been placed over the magnetics information (Figure 5a). Although this improves the interpretability and localization of targets of interest, it does not incorporate a rigorous statistical methodology. Here we present a statistical approach to successfully identify and locate remains within the subsurface by mathematically combining multi-sensor data into a coherent whole. Applying a standardization and statistical threshold to the data set proved to be a strong tool for delineating graves. Locations where HT magnetic, electromagnetic, or a combination of both signals surpass the two-sigma threshold are highlighted (Figure 5b).

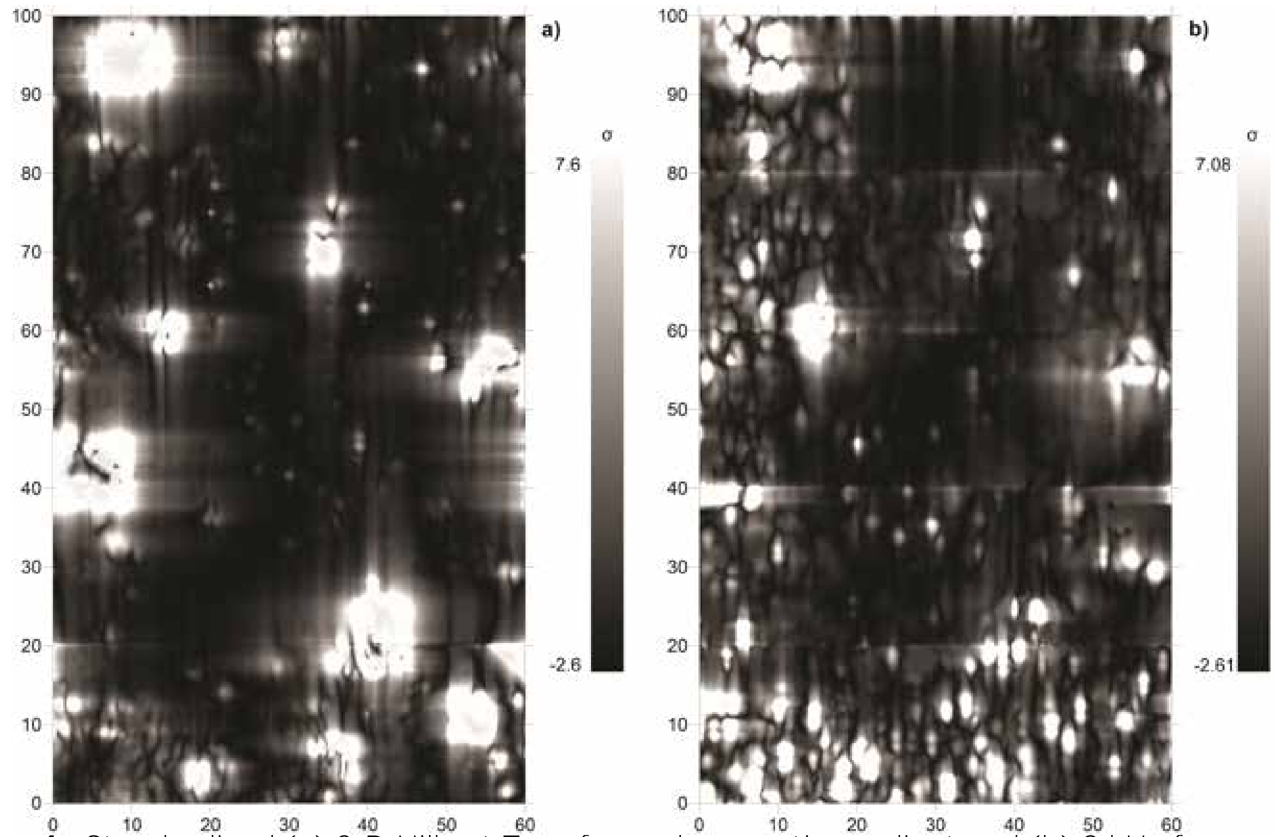

Figure 4: Standardized (a) 2-D Hilbert Transformed magnetic gradient and (b) 8 kHz frequency-domain electromagnetic-induction apparent electrical conductivity data.

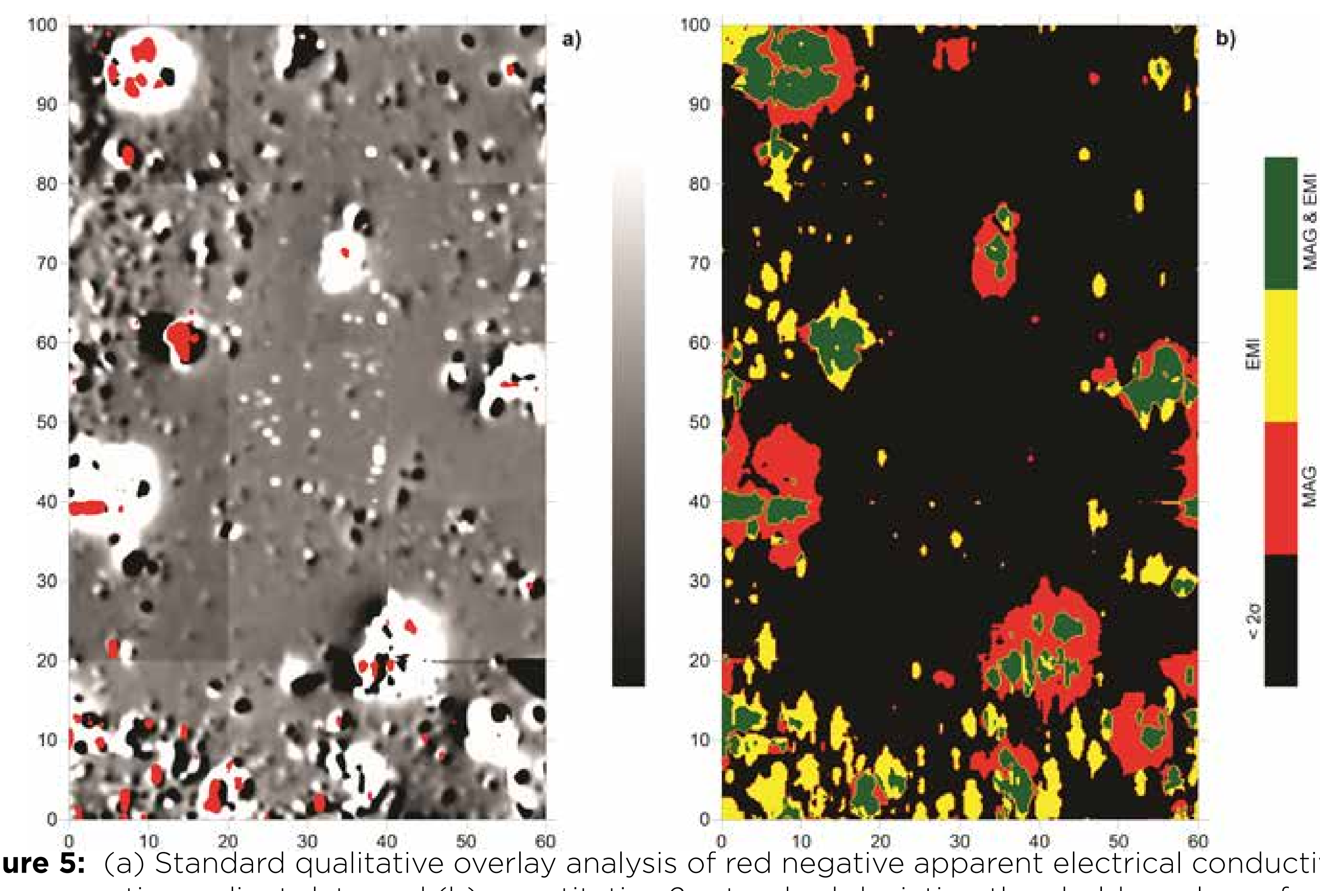

Figure 5: (a) Standard qualitative overlay analysis of red negative apparent electrical conductivities over magnetic gradient data and (b) quantitative 2σ standard deviation threshold overlays of magnetic gradient and 8 kHz apparent electrical conductivity data.

Historic iron fences border several well established family plots. These plots are clearly observable as the largest and boldest signatures. Imaged within Grid H, smaller, isolated signals take the form of casket-size projections. These cultural features are located in the clearest terrain of the cemetery. Many are located without headstones upon slight depressions in the cemetery soil. Observable from satellite imagery, within the southwestern corner of Grid A rests a large, concrete encasement (Figure 2b). Shown with graphical overlay techniques, the signature of the encased-casket surpasses the two-sigma threshold for both MAG and EMI (Figure 6).

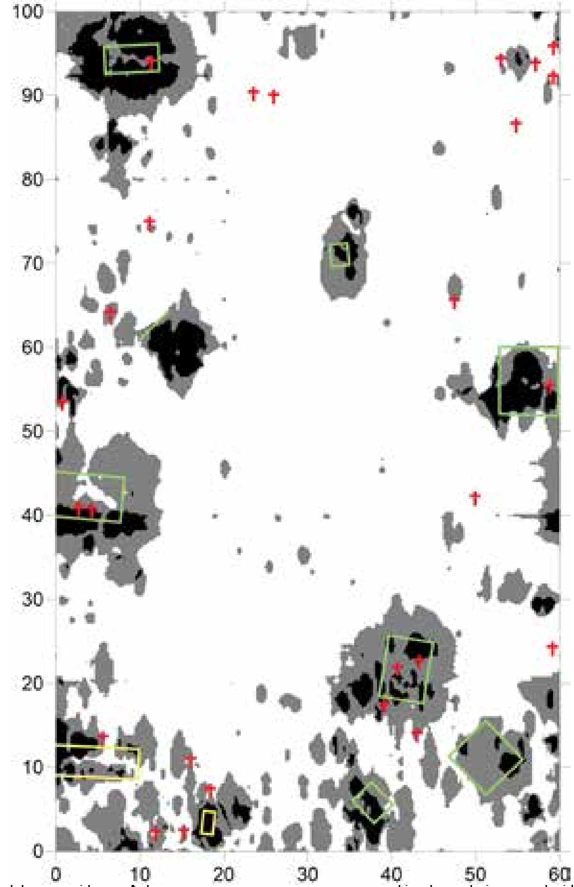

Figure 6: Interpretive map of the site. No graves are predicted in white areas, while grey areas detected possible graves with one method, and black areas suggest probable graves with two methods. Headstones locations are marked in red, concrete footings in yellow, and fences in green.

Incorporating Geophysics with High-Impact Student Learning and Community Archaeology

Eminent anthropologist Alfred L. Kroeber once said “it [anthropology] is the most humanistic of the sciences, while also the most scientific of the humanities” (Kroeber, 2003). Many archaeology research projects currently use methods developed in the ‘hard’ sciences - but with an anthropological lens - in order to understand more about past human cultural behaviors. This is an excellent example of E.O. Wilson’s (1998) consilience, the convergence of humanistic and scientific knowledge into a complete unified whole. Scientific methods are tools within the archaeological toolkit, which can be used to ask and answer questions about how people lived in the past.

Archaeology is an inherently tangible discipline that studies the cultural material manifestation of human symbolic and practical behaviors. When people hold artifacts that have not been seen or felt in many hundreds or thousands of years they transcend time and space by stepping back into another world - this is the magic and mystique of the discipline. Artifacts provide a direct emotional connection with the past, with our community and with all of humanity. Community outreach combined with applied geophysics and archaeology physically brought the past into the focus of the present by uncovering and restoring this once lost heritage.

Since the Fall 2014 semester, Texas A&M University's Geophysics 413 Near-Surface Applied Geophysics undergraduate course has conducted fieldwork at the Camptown African American cemetery in Brenham, Texas, collecting frequency-domain electromagnetic-induction, magnetic gradiometry, and ground-penetrating radar data. This hands-on class was comprehensive and research oriented in that the students learned to collect, analyze, process, and visualize these data, and finally to write up a report and interpret the results. The students learned by doing. Learning to collect data gave the students a sense of ownership of the class materials, where active experiential learning becomes the central focus of the course instead of the materials themselves. Processing these data are excellent exercises in the analytical, quantitative, and critical thinking skills necessary to make meaningful interpretations.

Near-surface geophysics was not the only skill learned in Geophysics 413. Students also learned how to collaborate with their fellow students in the field and their local community. Working with and providing a service to the Brenham community has helped Texas A&M University and the Department of Geology & Geophysics. This community work promotes geophysics and archaeology as a public interests and attracts future work for students. The project has helped the students to become active participants in the unity of STEM and social science research as the project objective is to locate unmarked African American burials from a period of extreme cultural tension.

Community and student involvement was of critical importance to the success of this project. In merging archaeology and geophysics within a high-impact learning and community archaeology project we bridged the divide of hard and soft science to bring about a more nuanced and holistic narrative about the perseverance of the African American community in Brenham, Texas. Recognition of those who founded this community is of enormous cultural and historical importance to the families and relatives of those who lived within Camptown. The story is not just about how people died in Brenham, but how they lived, and how their descendants in the community continue to remember and (re)interpret the past to this very day.

Conclusions

We greatly enjoy discussing the results of this work with the community. The geophysical heritage mapping was designed to be viewed intuitively, with an x-marks-the-spot interpretation. Community members have the opportunity to discover more about what is buried in their backyard, as the Camptown Cemetery work will be placed on display at the Brenham heritage museum. The most telling research incorporates multiple components. Placing geophysical results into this anthropogenic case provides a telling component for the story of Brenham's early Texas history. Camptown Cemetery is the resting place of the original Texans – those who lived throughout or fought in the Texas Revolution – the families of the first emancipated African Americans, Buffalo soldiers, and the American Veterans who bravely served in wars on American soil and overseas. The restoration of Camptown Cemetery was cared for by the hands of volunteers, up-keeping the unkempt. By volunteering in this civil and historical work, Texas A&M University and the Department of Geology & Geophysics has been a tremendous aide for their students and the community of Brenham. As a result of our involvement, contacts at other heritage sites were established; and work was secured for future students. By lending a hand at Camptown we have inspired residents of Brenham to reconsider the historic plight of enslaved people.

Just a few years ago this cemetery was a terribly ironic DEAD END (Figure 7). Now, much of the cemetery's overgrowth has been cleared. Fencing and headstones have been refurbished. Flowers and American flags have been planted as memorial for the loved ones and veterans from the community. Accordingly, the Texas Historical Commission dedicated the Camptown Cemetery and its Mount Rose Missionary Baptist Church a historic landmark in the Spring of 2014. A heritage once lost is now found.

Figure 7: Before (top) and after (bottom) pictures of the Camptown Cemetery. Where a DEAD END sign once stood is now a Historic Landmark marker, the once lost heritage of the community is now found again.

Acknowledgements

Reverend Eddie Harrison of the Mount Rose Missionary Baptist Church, a former judge, historian, and community activist, led a push to gain ownership of the cemetery and restore it. His hard work along with the Church, Rolling Thunder, Brenham Heritage Museum, "What's In Your Backyard" Public Archaeology Project, Texas A&M University, Dr. Mark Everett – professor of Geophysics 413 classes – and his students, and those who dedicated their time and patience made this project possible. They all deserve a great deal of thanks.

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THE ARCHAEOLOGICAL GEOPHYSICS PROGRAM AT THE UNIVERSITY OF KENTUCKY

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A Short History

The application of near-surface geophysical techniques to aid in the identification of buried features and exploration of archaeological sites is becoming a routine practice in many areas of North America (Johnson, 2006). Adapting techniques from environmental geophysics and influenced by the more common use of geophysical instruments in European archaeology, a few physicists and archaeologists in the U.S. began experimenting with these techniques in the 1970s and 1980s. Physicists such as John Weymouth at the University of Nebraska and Lewis Somers of Geoscan Research USA pioneered survey techniques specifically for archaeological applications, and archaeologists such as Lawrence Conyers at the University of Denver, Jay Johnson at the University of Mississippi, and Kenneth Kvamme at the University of Arkansas introduced archaeological geophysics into their curricula. Federal agencies, especially the National Park Service, have been active in promoting the use of these techniques for academic research and archaeological consulting work. For example, the NPS Midwest Archaeological Center in cooperation with the National Center for Preservation and Technology Training offers an annual workshop on archaeological prospection. 2015 was the 25th year of the workshop.

While only a few archaeologists may specialize in geophysics, all archaeologists should at least have a basic understanding of the various techniques and their practical application. In the late 2000s, the University of Kentucky archaeological program decided to create an archaeological geophysics lab where students could learn and experiment with various techniques applied to real-world situations. This would provide graduate students an opportunity to use geophysical prospection in their thesis research and undergraduate students the opportunity to gain experience in collecting and processing geophysical data. In today's job market, most students who specialize in archaeology will not obtain jobs in academia. Most will be employed in applied positions such as federal or state land managers who oversee archaeological sites on public property or as consulting archaeologists who identify and investigate sites that will be impacted by public construction

Keywords: University of Kentucky - Archaeological Geophysics Lab, Adena Earthwork and Mound Sites, Historic Jamestown - Virginia, Magnetometry, Ground-Penetrating Radar.

projects. Site excavation is a costly and labor intensive process. Geophysical surveying is an extremely useful tool for determining if a site may contain significant intact deposits, and if the site cannot be preserved, for designing cost effective excavations to recover the potential loss of information. Student with skills in archaeological geophysics are increasingly in demand. Even if they do not specialize in archaeological geophysics, to be effective land managers or consulting archaeologists, they must understand when geophysical surveying is useful and be able to evaluate the results of different techniques.

In 2007, with the aid of a National Science Foundation Major Research Instrumentation Grant, the University of Kentucky archaeological program purchased new instrumentation, software, and graphic intensive computers. The lab already owned an early model electromagnetic induction meter made by Geonics Limited (EM38 analog meter) and a Polycorder 720 datalogger. To this we added a resistance meter and fluxgate magnetometer (RM15-D and FM256 respectively, both made by Geoscan Research) and a Malå ground penetrating radar system (RAMAC CUII). These were state of the art instruments in 2007, and they have been work horses for our geophysical program, but the market has expanded and improved some of these systems over the past eight years. For example, temperature compensation circuitry greatly reduces temperature-related drift, which is a problem with early model EM38 instruments and the FM256 fluxgate gradiometer. Automatic calibration of sensor alignment on fluxgate gradiometers is also a more recent advance that can reduce setup and recalibration time in the field.

Because many features of interest in archaeological sites are small (less than 1 m in size) and often have very weak signatures, collecting geophysical data in most archaeological situations typically requires closely spaced transects, often at 50 cm or even 25 cm intervals. Archaeologists usually collect data in 20 x 20 m or 40 x 40 m grid units; so, for example, collecting resistance data in 50 cm transects at 50 cm intervals means picking up and placing the mobile probe array 1600 times in one 20 x 20 m grid unit (or using a 1 m parallel twin probe array—collecting two 50 cm readings parallel to each other on a 1 m boom—one can halve the number of probe insertions to 800 times per grid!). Compared to other techniques, resistivity has the longest data collection times. Also, making electrical contact with the ground can be problematic in dry or rocky conditions. These factors have limited the widespread use of resistivity in many archaeological applications. Magnetometry and GPR are the two most commonly used geophysical techniques in our practice, and probably among archaeologists in general.

Two more recent advances in geophysical prospection techniques are poised to improve the speed of data collection in archaeology several times over. First, is the development of multichannel sensors, especially in magnetometry. Geoscan Research and Bartington® Instruments have manufactured dual fluxgate gradiometer systems that are carried with a shoulder harness for some time now. However, even more convenient are multichannel magnetometers mounted on push carts or that can be trailed behind a vehicle. Foerster Instruments, Inc. and SENSYS GmbH each produce multichannel systems for archaeological applications. We have been testing a 5-channel SENSYS magnetometer with extremely good results (described below). The second advance is the use of Real Time Kinematic GPS to geo-reference all measurement points with an accuracy of 3.1 cm. This allows large tracts to be surveyed without the need to first establish a network of grid datums to guide the collection of geophysical data. Archaeologists considering the purchase of a new survey system will expect these to be standard options as the efficiency of such systems become widely known. The SENSYS magnetometer system is specifically designed to be used with RTK GPS and our older model Malå GPR has GPS capability but we have not used this option yet. Of course, the downside for a moderately funded social science, like archaeology, is that RTK GPS systems can cost nearly as much as the geophysical equipment. Fortunately, at the University of Kentucky, we are able to borrow some of the GPS equipment from other departments on campus.

Two Current Field Projects

In November, 2014, with the assistance of Gorden Konieczek of SENSYS, we began survey of a large Adena earthwork site In Woodford County, Kentucky, that is about 10 ha in size. Using the SENSYS MXPDA 5-channel magnetometer with a Trimble R7 GNSS receiver as a base station and a UHF external radio to communicate with a roving GPS receiver on the magnetometer, more than one third of the site was surveyed in a single day (Figure 1). Adena earthwork and mound sites, dating from 2500 to 1700 years ago, are common in the Bluegrass Region of Kentucky. The site, known as 15Wd2, is in a pasture at the confluence of three creeks. Historical plowing and flooding of this bottomland has erased evidence of the earthwork on the surface, but a 1790s drawing indicates the site was roughly circular in plan with deep ditches and embankments outlining the boundary. Several internal embankments were also present. The organically enriched sediments that have filled in these earthworks typically have a stronger magnetic signature than the surrounding alluvial deposits. Most of these earthwork sites have few artifacts or evidence of habitation, suggesting that the sites were built for cosmological or ritual purposes. Earthwork sites are often enigmatic and have varied uses. Some are associated with human burial and cremation ritual, others are associated with significant landscape features such as springs or prominent bluffs, and others appear to be constructed with respect to celestial observations. Magnetometry has been especially useful for identifying these sites and determining their internal patterns (e.g., Burks, 2014; Burks and Cook, 2011; Henry, 2011).

We plan to complete the survey of 15Wd2 in the near future, but the pasture is used for thoroughbred race horses and we must work around the schedule of the owner when horses and foals are in the field. After the geophysical survey, we will take sediment cores across selected features and segments of the earthwork to confirm their location and determine depths of the features. We also hope obtain charcoal from the ditch that can radiocarbon date its construction. If permitted by the landowner, we would like to excavate a small trench across a ditch to examine the stratigraphic profile of the earthwork in more detail than can be obtained from sediment cores.

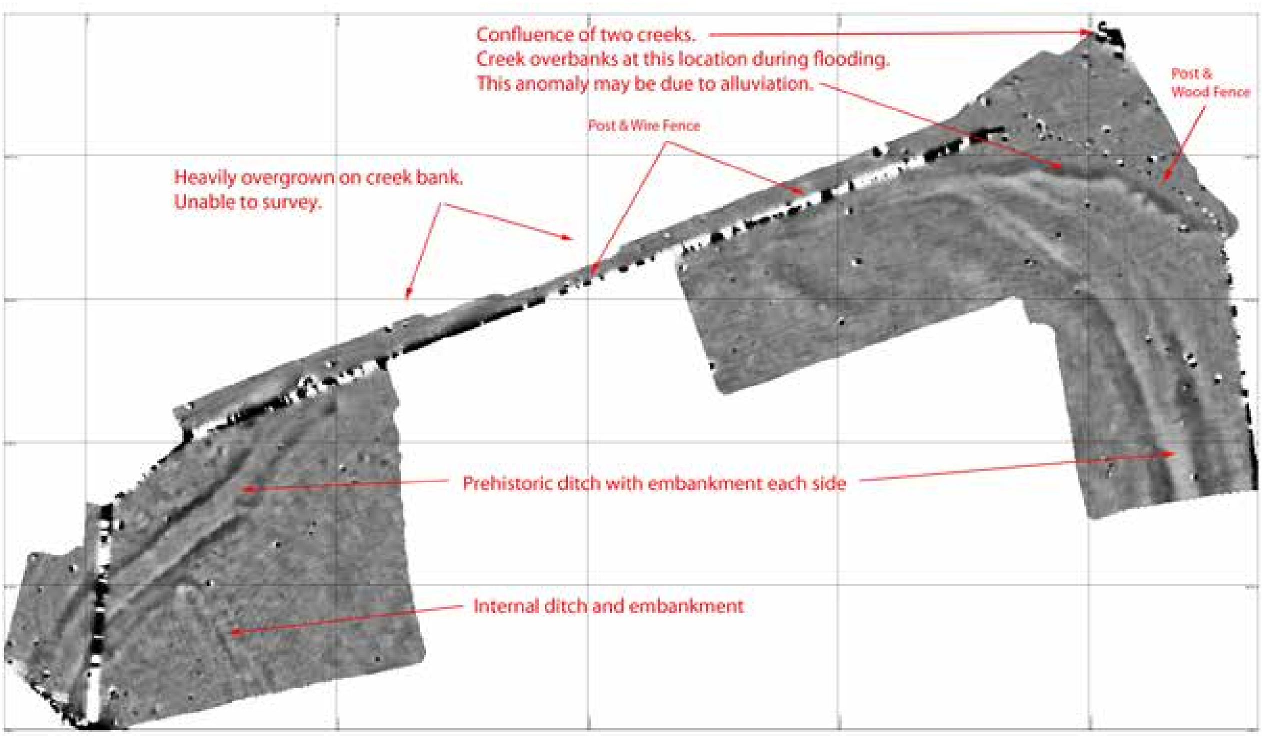

Figure 1: Fluxgate gradiometer survey of site 15Wd2 using a SENSYS MXPDA 5-channel magnetometer with 50 cm spacing between sensors. Data was processed with DLMGPS to link the sensor data to GPS coordinates and then further processed with SENSYS MAGNETO® ARCH, specifically designed for archaeological geophysics data. North is to the top. Grid lines measure 36.18 m in the X direction and 63.30 m in the Y direction.

Also taking place in November, 2014, a team from Kentucky traveled to historic Jamestown, Virginia, the site of the first permanent English settlement in America, at the invitation of the Jamestown Rediscovery Foundation to conduct a preliminary geophysical survey as a demonstration project. Although some magnetometry was employed, we concentrated on collecting GPR data as the most appropriate technique to use on this complicated site. Although the English settlement dates to 1607, the site has been used for many purposes, including as a Confederate battery during the American Civil War. In the 1890s the site was privately purchased for the purpose of preserving it. Today, Preservation Virginia, a non-profit organization, jointly administers the site with the National Park Service who owns the rest of Jamestown Island. Since 1994, there have been continuous excavations at the site through the Jamestown Rediscovery Foundation, but only a small portion of this large site has been excavated. The site receives large number of visitors, who can watch archaeologists in action, and is an important public education program on both the history of Jamestown and the science of archaeology. A description of our work at Jamestown can be found on their website.

Using the Malå RAMAC CUII with a 500 MHz shielded antenna on a push cart equipped with a pulse encoder for distance triggering several areas of the site were surveyed. In the time slices shown in Figure 2 modern features are revealed in the upper slices that appear to be reflecting a gravel path and two utility lines. However, beginning at the 51-62 cm slice a very intense reflection shown in red appears as a cylinder-like anomaly that is still evident in the deepest slice at 192-202 cm. Our initial thought is that this may be a well. It is not evident whether it dates to the original settlement, but future excavations will be able to determine its construction and age.

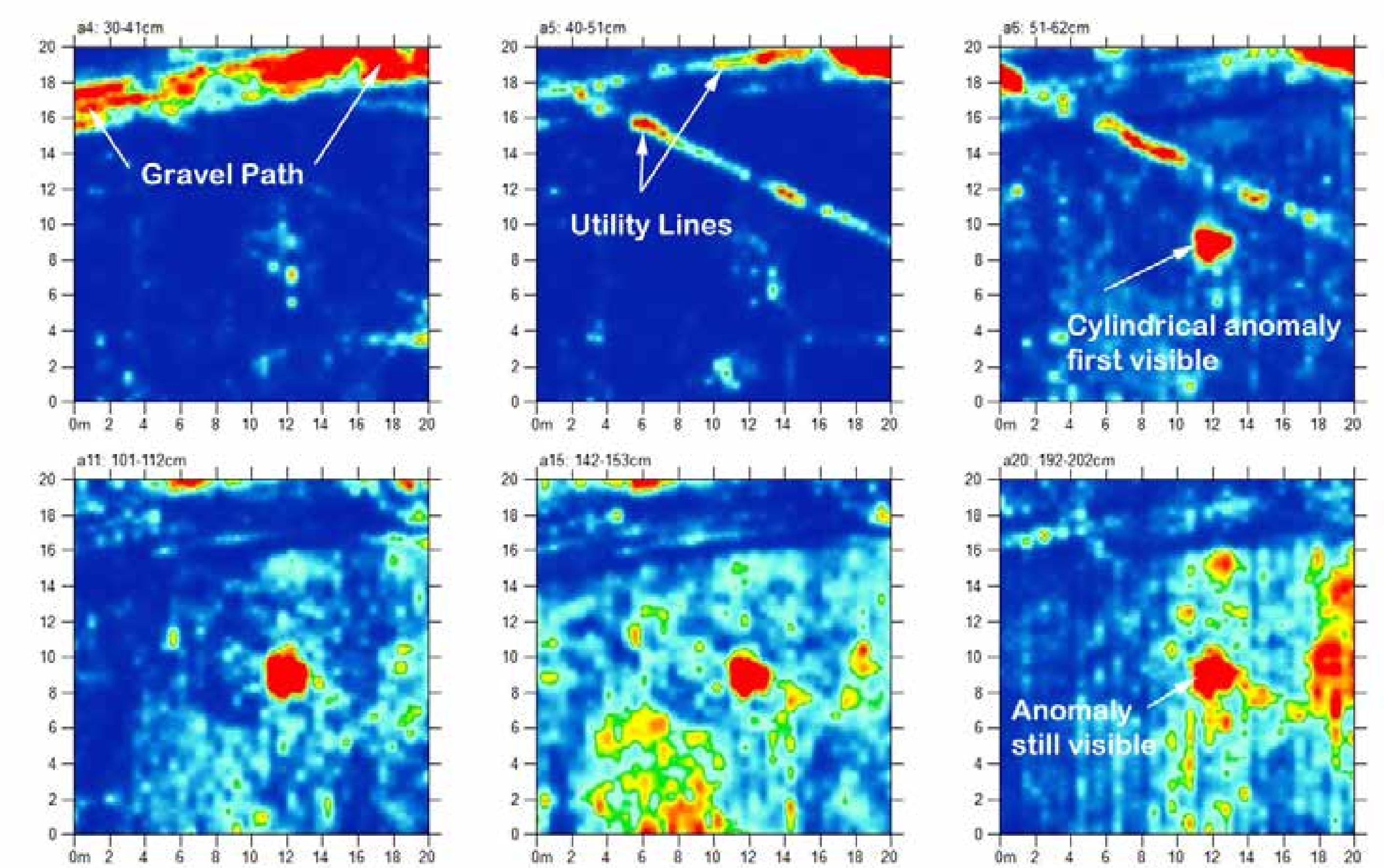

Figure 2: Selected time slices of historic Jamestown survey using a Malå RAMAC CUII ground penetrating radar with a 500 MHz antenna. Data was processed with GPR-Slice 7.0. a4: 30-41cm, clearly shows a gravel path/road visible on the surface. a5: 40-51cm, two utility lines crossing each other are evident in the upper portion of the image. a6: 51-62cm, the large, highly reflective anomaly is first visible in this slice. This cylindrical feature remains visible through the remainder of the slices to a depth of 202 cm. This feature may be a well, but has yet to be excavated.

Jamestown Rediscovery has incorporated some of our results into their current excavation program that is described here. We were able to cover only a small portion of the total site area in our two days of field work, but we hope that a longer-term cooperative project between the National Park Service, Jamestown Rediscovery, and the University of Kentucky can be initiated to survey more of the site. GPR and the multichannel magnetometer would be good instruments to employ on this site to cover large areas and provide complementary data for Jamestown Rediscovery to use in future excavation plans. Especially vulnerable are portions of the site along the James River that are being lost to bank erosion. This area would be a high priority for survey to determine if any archaeological features are evident, and if verified with small test excavations, plans could be developed to either reinforce the bank from further erosion or conduct more complete excavations before the features are lost.

Concluding Remarks

The University of Kentucky Archaeological Geophysical lab does provide contract services for small cultural resource management projects, but by and large, the primary mission of the lab is to provide students with the tools and the opportunity to learn and practice geophysical survey techniques. The majority of these projects are for student thesis research and non-profit cooperative projects with public outreach components that also provide opportunities for students and sometimes volunteers to assist with the data collection. Although we work primarily in the Southeastern and Midwestern U.S., students and staff have conducted geophysical surveys in other areas, including Grand Canyon National Park, Italy, Mexico, and Peru. Some of our students are now employed with private consulting firms conducting archaeological geophysics as a significant portion of their job responsibilities. Other students who are in academic positions are now developing archaeological geophysics programs at new institutions. While our archaeological geophysics lab is only a small part of our overall academic program, we believe it is an important addition to the program. If resources permit, in the near future, we would like to add a full-time dedicated archaeological geophysics specialist to the research staff or the faculty.

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A MAGNETOMETER SURVEY AT THE CONFEDERATE POW CAMP SITE OF CAMP LAWTON IN JENKINS COUNTY, GEORGIA

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Abstract

On February 15, 2015, a magnetometer survey was performed on four test areas at the site of Camp Lawton on Magnolia Springs State Park property. The goal of the survey was to identify subsurface targets and artifacts associated with the Confederate occupation that occurred in October-November 1864. The survey successfully identified numerous magnetic anomalies that represent possible buried features and clusters of artifacts. While some of these undoubtedly are associated with the mid-20th century CCC occupation at the site, future testing will determine which of these, if any, are associated with the Civil War era occupation.

Introduction

On February 15, 2015, a magnetometer survey was performed by Bigman Geophysical, LLC on four test areas at the site of Camp Lawton in Jenkins County, Georgia (Figure 1). The magnetometer survey serves as one of several methods being used to locate Confederate loci at Camp Lawton. However, the primary goal of the magnetometer survey was to guide test excavations, and will be an integral part of the larger archaeological research project organized by Georgia Southern University.

Camp Lawton was a Confederate POW camp constructed during the late summer of 1864. It was constructed to relieve overcrowding from Camp Sumter, more commonly known as Andersonville. Camp Lawton was built to hold tens of thousands of prisoners, and the stockade encompassed roughly 42 acres. The camp opened in early October, but was abandoned in late November, as Sherman's army approached from the northwest (Derden, 2012).

The site of Camp Lawton is located three miles north of Millen, Georgia, about 45 miles south of Augusta. Much of the site is contained within the boundaries of U.S. Fish and Wildlife Service land and Magnolia Springs State Park. The four test areas, labeled Test Areas 4-7, range in size from

Keywords: Camp Lawton, Confederate POW Camp, Magnetometry, Fluxgate Gradiometers, Cesium-Vapor Total Field Magnetometer, Magnetic Anomalies.

220m x 80m to 30m x 30m (Figure 2). The areas were identified as likely to contain Confederate occupations, based on Civil War era maps and on current landforms and proximity to the stockade, earthen fort, and the Magnolia Springs drainage. The geological material is composed of sand, but one limitation of this study is in presence of iron concretions in the subsurface. These iron concretions have a higher magnetic susceptibility than the background soil and may cause false positives in the data by mimicking the signature of artifacts.

The results of the magnetometer survey show, particularly in Test Area 4, numerous anomalies that represent the locations of possible buried archaeological targets such as pits, individual artifacts, or artifact clusters. The temporal period for most of these anomalies is currently unknown. Many probably are associated with the CCC camp that was located at the park in the 1930-1940s. Future test unit excavations will hopefully determine which of these anomalies if any, date to the Civil War era.

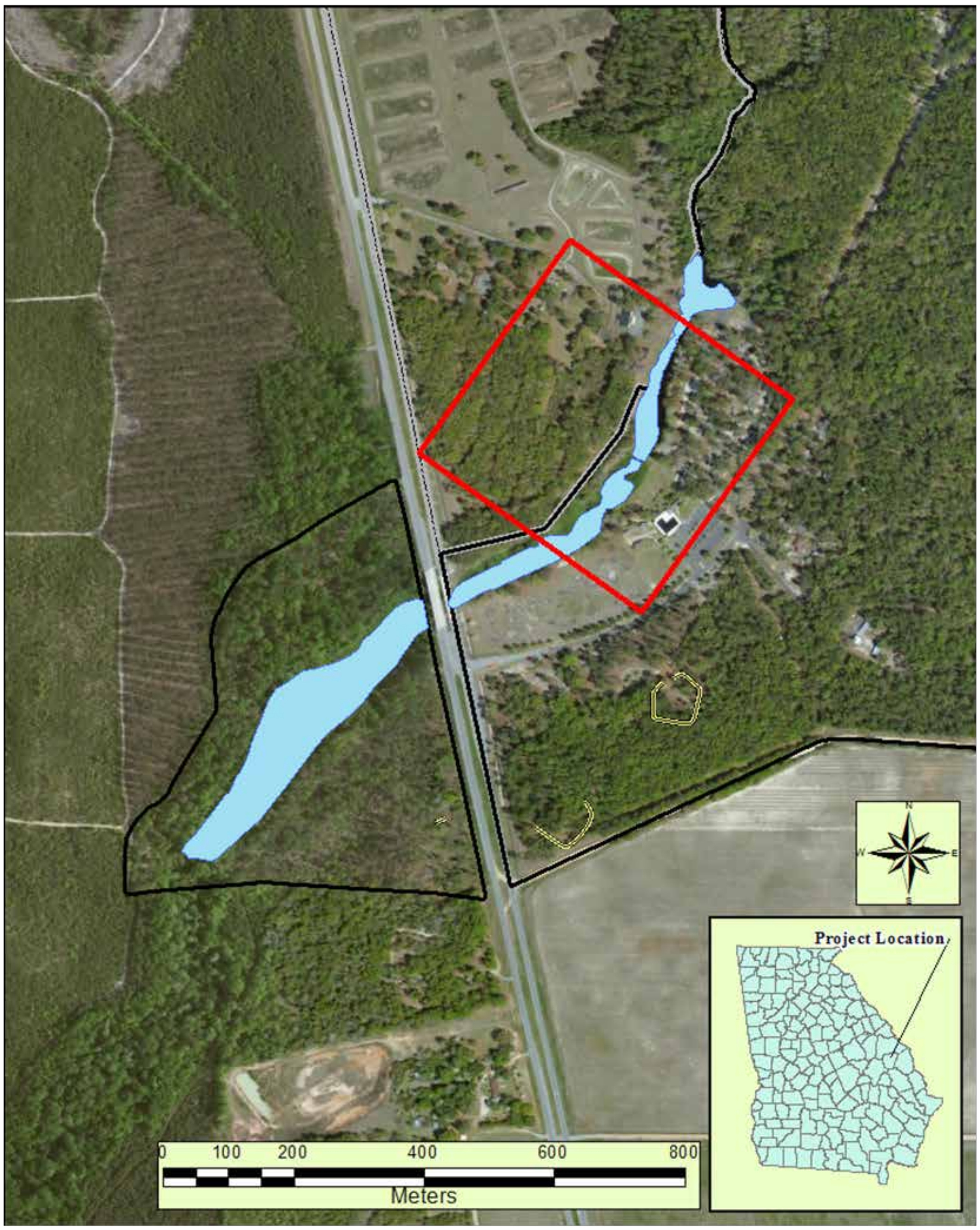

Figure 1: Location of Camp Lawton archaeological site.

Figure 2: Locations of Test Areas 4-7 on Magnolia Springs State Park.

Methods

Magnetometry measures local variations in the earth magnetic field strength. It is a passive method of prospection in that it records the earth's field rather than generating an artificial field and measuring the earth's response (such as electromagnetic induction). Often the goal of magnetometry in archaeology is to identify short-wavelength variations (anomalies) produced by archaeological sources (Kvamme, 2006a).

There are two basic types of magnetism that produce variations in the earth's local field strength as a result of past human activity: thermoremanent magnetism and magnetic susceptibility (Aspinall et al., 2008). Thermoremanent magnetism occurs when soils or objects are fired above the Curie temperature and the magnetic moments become parallel. Upon cooling, the moments may remain parallel creating a permanent magnetic intensity. Parallel magnetic moments increase the overall field strength of the soil or object and is easily detectable with a magnetometer.

Magnetic susceptibility refers to the ability of a material to become magnetized (Kvamme, 2006a). This primarily depends on the presence of magnetizable minerals, which in soil essentially consists of hematite, magnetite, and maghemite (however, only the last two are significantly magnetic) (Clark, 1997). There are four different processes that can enhance the magnetic susceptibility in soils: (1) iron accumulates naturally in topsoils, (2) alternating periods of wetness and dryness can transmutate hematites to maghemites, (3) fires reduce hematite to magnetite, and (4) some colonizing bacteria in organic soils can excrete maghemite (Kvamme, 2006a). Human activity can exacerbate these processes and enhance the magnetic susceptibility of soils (Dalan, 2006).

This project collected data for Areas 4, 5, and 7 using three Ferex fluxgate gradiometers mounted on a pushcart with a survey wheel. Due to the multiple sensors and the cart system, this survey was able to collect very high-resolution data. The sensors were spaced 0.5 m apart with a transect interval of 0.5 m. The surveyor collected data at a sampling interval of 20 cm, with an automatic fiduciary marker recorded every 1 m with the survey wheel in order to limit error. The project attempted to collect data in 40m x 40m grids, but grid sizes had to be reduced on occasion due to surface obstructions. Such obstructions included trees, civil war earthworks, and park infrastructure such as the entrance gate.

Magnetic data for Test Areas 4, 5, and 7 were processed using Data2Line software. Our processing procedure generally followed the suggestion of Kvamme (2006b), where we filtered data first and enhanced images second. Individual grids were de-staggered to correct for shifts in data locations due to inconsistencies in surveyor speed or lags in recording from the instrument. Next, we applied a zero-mean traverse filter to each transect to compensate for heading errors and instrument drift. Finally, we smoothed the data using a 5m x 5m low-pass filter to remove noise and facilitate interpretation.

The survey collected data in Test Area 6 using a G-858 cesium-vapor total field magnetometer manufactured by Geometrix. Data were collected in continuous mode with readings recorded every 1/10 of a second and the surveyor collected transects at a spacing of 1 m. All data from Area 6 were processed using MagPick software. A zero-median traverse filter was applied to each transect to correct for diurnal drift, variation in topography, and variation in background susceptibility.

Results

The survey recorded magnetic anomalies in each area with varying signatures, each representing changes in the local field strength from different sources. The signatures of these anomalies fall into three categories, 1) localized clusters of magnetic highs and lows which we interpret as artifact clusters likely consisting in part of metal objects, 2) isolated dipolar anomalies of approximately equal positive and negative responses likely created by single metal objects of historic or modern origin, and 3) positive magnetic anomalies that likely represent pits, burials, organic remains, filled in ditches, etc.

Area 4

Area 4 is a rectangular block measuring 220m x 80m, located in a large field bordering the south side of Magnolia Springs Creek (Figure 3). The most overwhelming feature mapped with the magnetometer is the probable historic drainage system located in the approximate center of Area 4. This feature consists of a grid of positive magnetic anomalies on the eastern side of the feature, each approximately 1 m in diameter, surrounded by negative magnetic readings. The western side of this feature consists of liner magnetic anomalies oriented approximately northeast-southwest. These are interpreted as trenches.

Numerous isolated dipolar anomalies are distributed across Area 4 (Figure 4). It is impossible to distinguish between historic and modern sources for these anomalies. However, the magnetometer recorded seven possible artifact clusters in Area 4 possibly historic in date. It appears that the trenches of the historic drainage system disturbed the archaeological record and at least one artifact cluster extends into this feature. These may be clusters of iron concretions and we offer our identifications of artifact clusters with caution. Finally, numerous mono-polar magnetic anomalies interpreted as pits are located throughout the survey area and range in size. While the smaller mono-polar anomalies recorded here with the magnetometer may indicate remains of graves, fire pits or decayed post holes, it is likely that at least some are the products of bioturbation. The larger examples likely do represent pits or ditches possibly of Civil War date in origin.

Figure 3: Results of Test Area 4 Magnetometer survey.

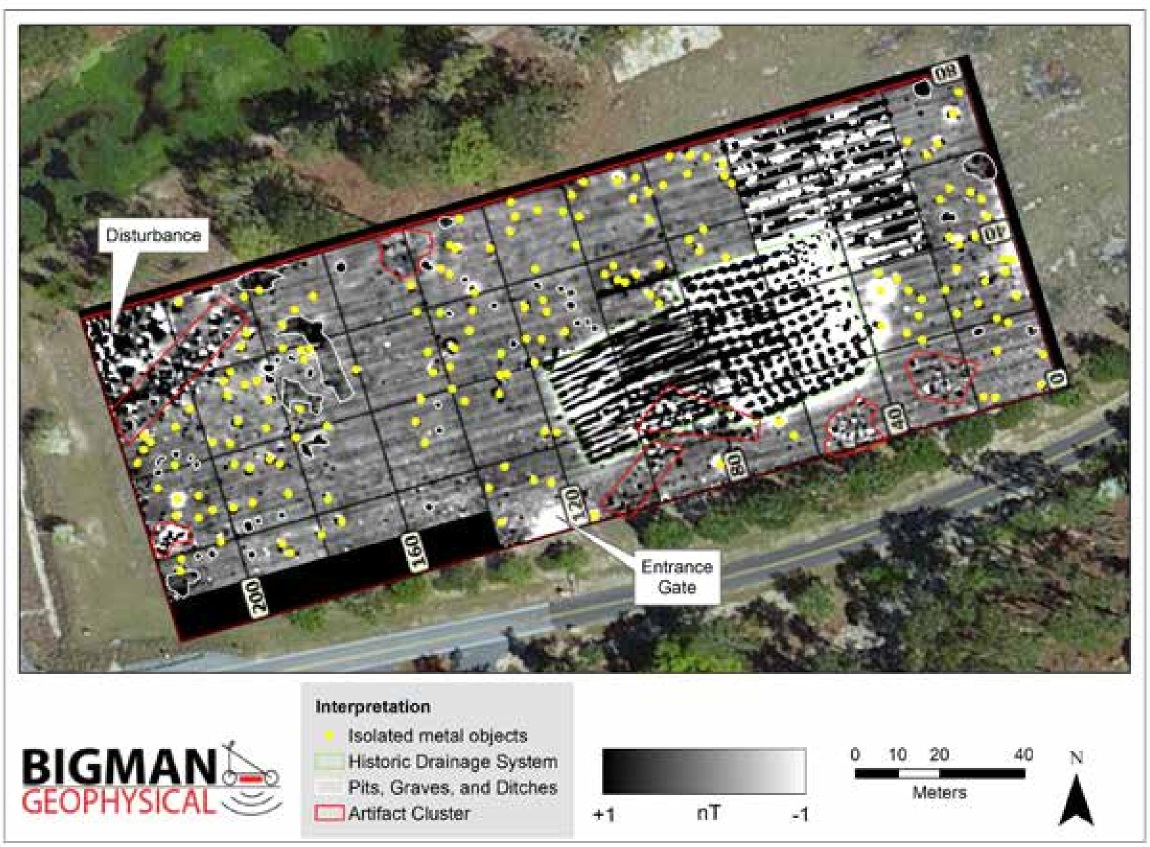

Figure 4: Results of Test Area 4 Magnetometer survey with anomalies highlighted.

Area 5

Test Area 5 (Figure 5) measures 40m x 40m, and is located west of Highway 25 and north of the creek. The data collected in this forested area is virtually un-interpretable. The magnetometer recorded significant variation across the entire grid; however, some of this variation is likely the result of root disturbance, bushes, and other obstructions limiting the quality of data collection. In addition, historic objects, modern trash, and concrete were distributed across the survey grid and several small cavities were present in the shallow subsurface. Mid-20th century aerial photographs show that the CCC had erected several small buildings in the vicinity, and many of the anomalies undoubtedly are associated with these disturbances. The magnetometer data provide little useful information to help better understand the Civil War occupation in this area of the site.

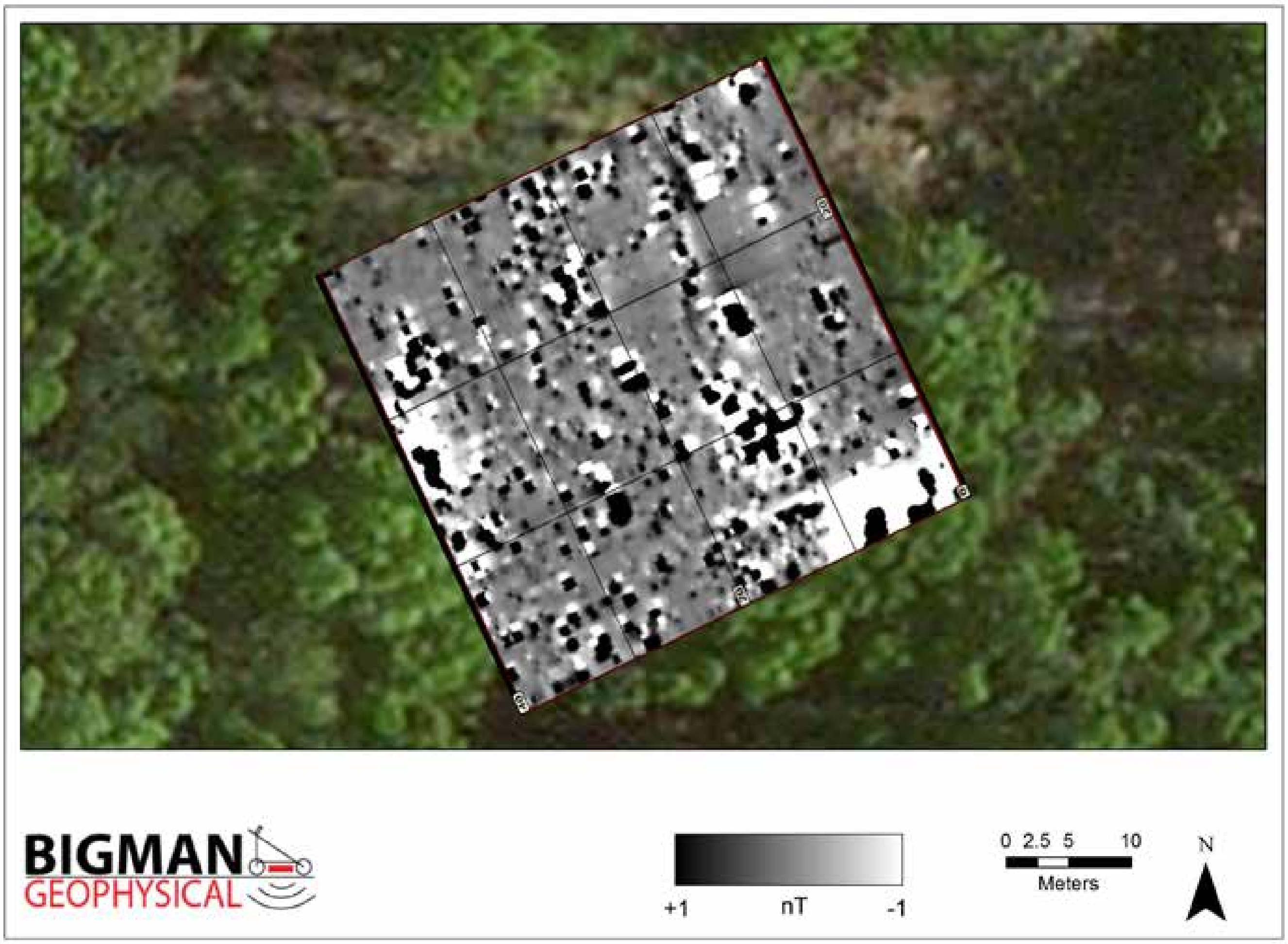

Figure 5: Results of Test Area 5 Magnetometer survey.

Area 6

Test Area 6 is located south of Test Area 4 and the entrance road to the MSSP. It measures 60m x 20m, and encompasses a narrow, deep drainage ditch. It is likely that this landscape feature represents a natural spring drainage that flowed into the Magnolia Springs Creek. Data collected in Area 6 (Figure 6) revealed little information directly attributable to Civil War activity. A cluster of anomalous readings located in the southeastern corner of the survey grid likely reflect more recent historical activity. Archaeological evidence indicates that the CCC used this area as a dump for architectural debris. While not directly related to the Civil War, the history of the CCC is valuable in its own right. The gully descends northward down the slope and anomalous magnetic readings trail into the gully. This suggests that erosion is moving historical artifacts from their original location.

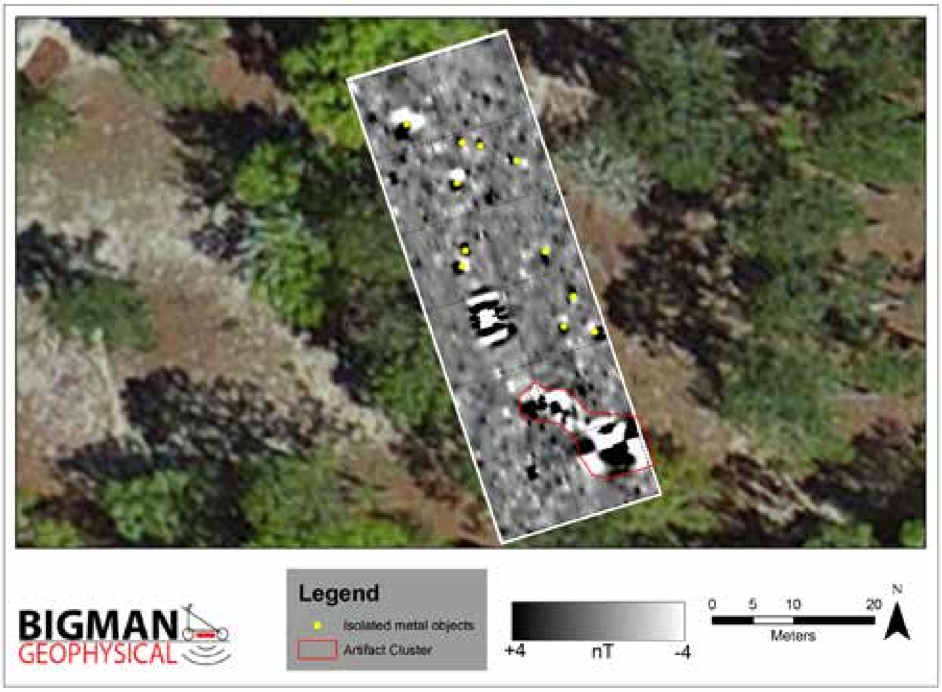

Figure 6: Results of Test Area 6 Magnetometer survey with anomalies highlighted.

Area 7

Test Are 7 is a 30m x 30m block situated within the earthen fort. There is little to no evidence inside the earthen embankment indicative of a building (Figure 7). There is generally a variable distribution of magnetic values in the southwestern portion of the survey block, but it is unclear if this represents a cluster of artifacts or disturbance. There are two distinct high amplitude di-polar anomalies in the northwestern portion of the survey block (near the entrance) which likely derive from metal sources. Finally, there is a cluster of generally positive magnetic anomalies in the northeastern portion of the survey block, near the gun ramp. This may represent pits or artifact clustering. However, the location near the bottom of the ramp may indicate eroded soils of a more organic origin and higher magnetic susceptibility.

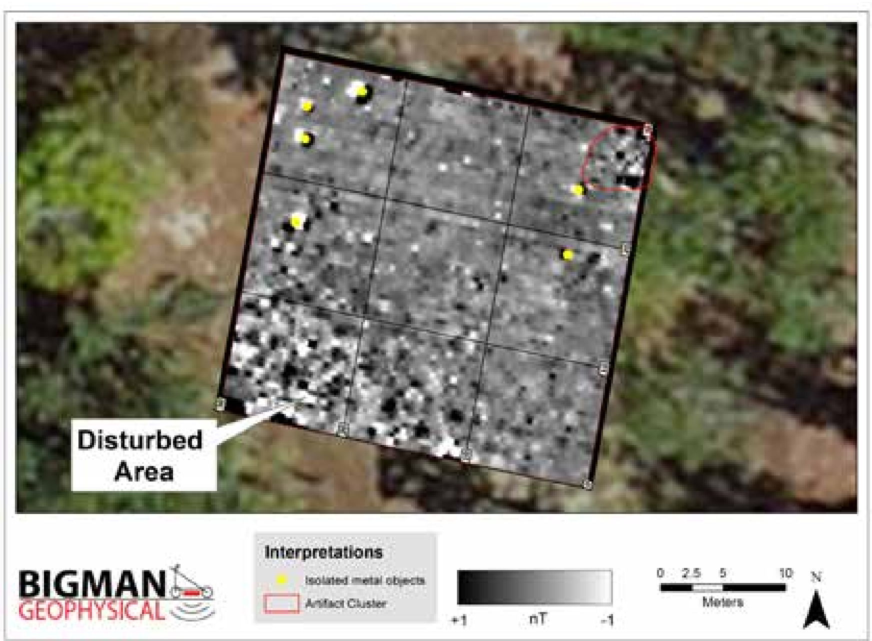

Figure 7: Results of Test Area 7 magnetometer survey with interpretations.

Conclusions

A magnetometer survey was performed on four test areas of the Camp Lawton site on MSSP property. The goal of the survey was to identify subsurface deposits associated with the Confederate occupation at the site. In test areas 4, 6, and 7, anomalies were identified that may be buried features and artifacts/artifact clusters. The mid-20th century drain fields in Test Area 4 are the most clearly identified pattern. Other anomalies, such as those in Test Area 6, have been identified, through archaeological testing, as CCC related. However, numerous anomalies in Test Area 4, and a smaller number in Test Area 7, may represent Civil War era cultural features and artifacts. The magnetometer data from Test Area 5 are inconclusive. This is probably due to the ground disturbance caused by construction in this area by the CCC in the mid-20th century. The magnetometer data provide evidence of possible subsurface deposits and artifacts, particularly in Test Area 4. There are several limitations to the study such as indistinguishable dates for most anomalies and the presence of buried iron concretions, but these data should be useful in guiding future excavations.

Acknowledgements

We would like to thank Dustin Fuller of the MSSP and Bryan Tucker of the Georgia DNR Historic Preservation Division for making this investigation possible.

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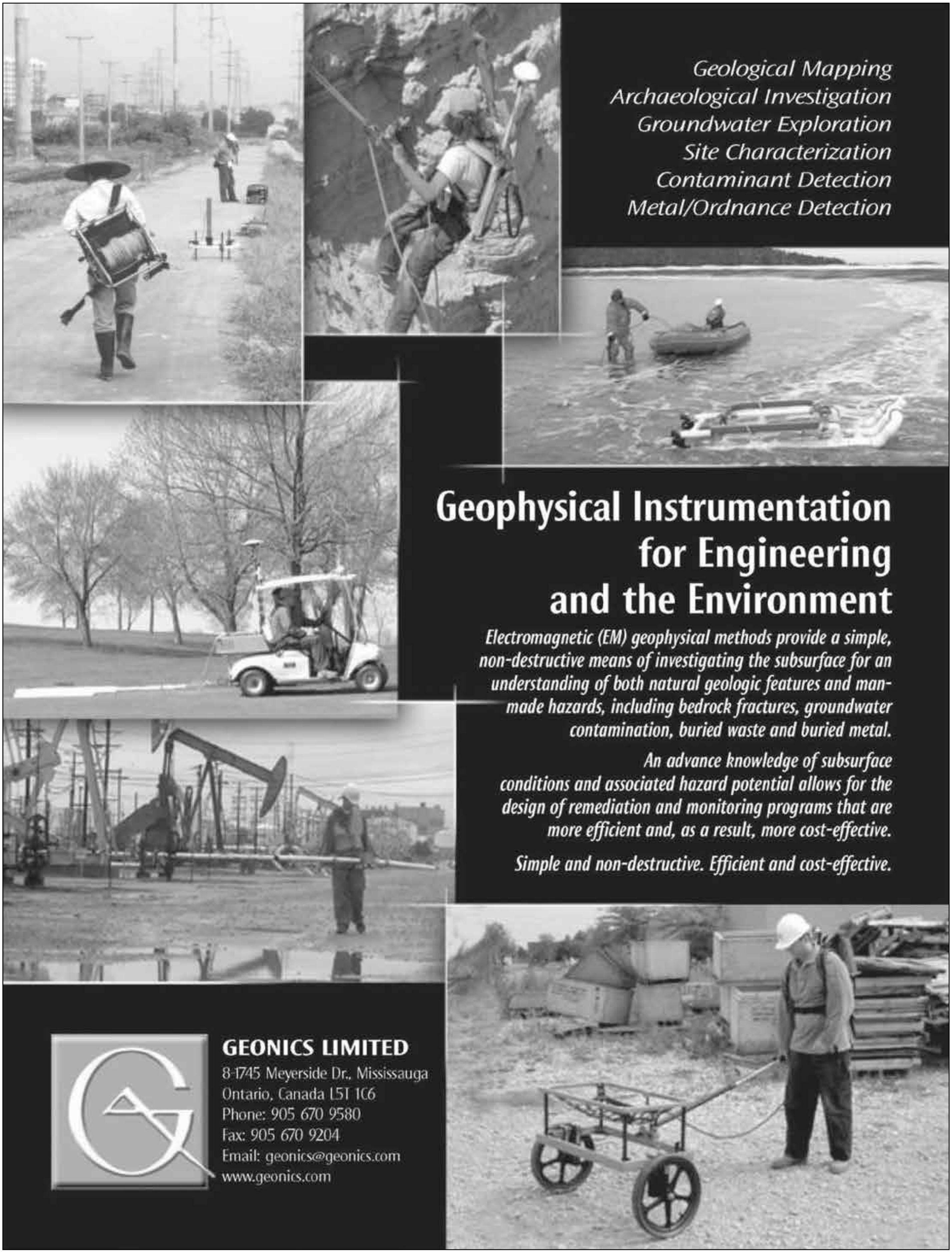
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GPR-SLICE v7.0 Ground Penetrating Radar Imaging Software (©1994-2015)

The Geophysical Archaeometry Laboratory announces the release of yaw/pith/roll corrections for radargrams and 3D volumes in GPR-SLICE v.7.0 Ground Penetrating Radar Imaging Software (www.gpr-survey.com). GPR-SLICE is a comprehensive geophysical software designed for the creation of 2D/3D subsurface images for use in a variety of geotechnical, engineering and archaeological applications. Since its release in 1994, the software has continued to be updated and is a user driven software with updates meeting the needs of a diverse subscriber base. GPR-SLICE is integrated with all the worldwide GPR manufacturers and supports both single channel and multichannel equipment. GPR-SLICE is the first professional GPR software to provide for Vector imaging that corrects for roll/yaw/pitch of the antenna using either real time tilt meters synced to the radargrams or vector estimates from surface normal on topographic sites. GPR-SLICE reads the random GPS or total station tracks from every manufacturer's proprietary navigation log files and seamlessly does proper interpolation between tracks to create 2D depth slices and 3D volumes. Various interpolation algorithms can be used to generate GPS or total station time slices. For high density radar lines direct-to-volume menus without interpolation operations can be launched. GPR-SLICE's GPS Track menu has filtering capabilities to edit tracks in order to correct for the multitude of recording issues that can occur with GPS collection and fallout. GPR-SLICE has complete topographic corrections for 2D or 3D displays. GPR-SLICE 3D corrections in OpenGL use graphic warping of a draped topographic grid file to adjust volume and radargram displays in real time including isosurfaces. GPR-SLICE has advanced a Horizon Detection and Mapping menu that can work in batch mode to detect up to 8 layers all with independent velocities along with horizon exports for reports. Concrete imaging in GPR-SLICE uses specialized XY decoupled gridding operations plus radargram signal processes where X and Y lines are separated, elliptically gridded and then recombined with grid math operations to create the highest resolution 3D volumes. AutoCAD 3D DXF exports of drawn features within the 3D volume are exportable for quick mapping of utilities, rebar, graves, etc. BlueBox Batch © macros are available with complete operations from raw radargrams to processed radargrams through compilation of interpolated 3D volumes with a single button click in GPR-SLICE and are available for single channel and multichannel equipment. GPR-SLICE has automatic hyperbola detection and peak amplitude reporting for creating grid maps related to bridgedeck deterioration. GPR-SLICE currently has over 210 organizations worldwide actively subscribing to the latest version of the software. GPR-SLICE has an active Facebook forum where users discuss software operations.

GRL Dynamic Measurements and Analyses
engineers, inc.

March 19, 2015

For immediate release

GRL Engineers, Inc. has announced the March 16 opening of its 10th Branch Office, in the Houston metropolitan area. "We will be opening this office to better serve the needs of our growing client base in Texas", said Pat Hannigan, President of GRL.

The office will be staffed by Brandon Phetteplace and managed by Camilo Alvarez, who together will bring more than 22 years of experience in dynamic testing and quality assurance methods for deep foundations to the Texas market. Both Brandon and Camilo hold Master level certificates on the PDCA/PDI Dynamic Measurement and Analysis Proficiency Test.

Camilo, who has a MS in Civil Engineering from Case Western Reserve University, is well published and a registered professional engineer in multiple states. Camilo will manage the Texas office in addition to the Colorado and California offices. Brandon has a BS in Civil Engineering from Case Western Reserve University in Cleveland, Ohio and a BS in Physics from the State University of New York at Fredonia.

As all other GRL offices, the Texas office will provide dynamic testing services (PDA) on driven pile foundations as well as dynamic load testing (DLT), thermal integrity profiling (TIP), crosshole sonic logging (CSL), and low strain integrity testing (PIT) services for drilled shafts and augered cast-in-place piles. The office will also provide wave equation analysis, SPT Hammer and Becker Drill calibration, and other specialty services and analyses.

Brandon may be reached at BPhetteplace@GRLengineers.com or 832-389-1156. For more information on GRL testing and analyses services visit www.GRLengineers.com.

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COMING EVENTS AND ANNOUNCEMENTS

Call For Sessions:

Please send suggestions for possible sessions to Technical Chair Charles Stoyer, Interpex Limited, Golden CO, charles@interpex.com.

Planned sessions include:

APPLICATIONS FOCUS

Agricultural Geophysics
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Engineering Geophysics
Geophysics and Geologic Hazards
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Geophysics in the Oilfield: Contaminants, Water Demand, Induced Seismicity, and Hydraulic Fracturing
Integrated Near Surface Geophysics Case Histories
Material Property Measurements
Mining and Reclamation Geophysics
Non-technical Issues and Barriers to Applications of Geophysics
Polar and Planetary Geophysics
Transportation and Infrastructure Geophysics
UXO and UXO Sensor Technology

METHODS FOCUS

Airborne Geophysics, Remote Sensing, and UAV (Drone)-based Surveys
Borehole Geophysics
Electromagnetics and Magnetotellurics
Geophysical Database Management
GPR and EMI in Complex Environments: Emerging Concepts, Methods, and Data Analysis
GPR Instruments, Acquisition, Processing, and Analysis
Gravity and Magnetic Methods: Engineering and Environmental Applications
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Near Surface Seismic Reflection and Refraction
NMR for Near-surface Investigations (Development and Applications)
Novel Environmental/NS Geophysics Methods
Resistivity/Induced Polarization/Self-Potential Methods and Applications
Shallow Marine and Underwater Geophysics
Surface-wave Seismology for Engineering and Environmental Geophysics (Ken Stokoe Honorary Session)

Workshops planned:

Drones for Geology, chaired by Ron Bell, IGS Denver
Dams and Levees Summit, chaired by Willam E. Doll, Battelle

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COMING EVENTS AND ANNOUNCEMENTS

2015 John Nicholl Memorial Award Recipient - Bruce Smith

Dr. Bruce D. Smith was named the first recipient of the John Nicholl Memorial Award (formerly named the Gold Award) in Austin, Texas at SAGEEP 2015. Bruce is a research geophysicist with the U.S. Geological Survey, where he has worked since completing his graduate studies. Bruce's early work with the USGS was mineral exploration geophysics specializing in spectral induced polarization. Bruce led a mineral resource assessment of Native American lands, flying airborne surveys over seven Great Lakes reservations, then directed the follow up ground geophysical work. He pioneered the use of ground and airborne geophysical methods for environmental studies applying the first helicopter EM surveys to study abandoned mine lands and acid mine drainage. Bruce continues to apply geophysical techniques to a broad range of issues including karst mapping, identifying impacts of produced waters, and aquifer mapping.

Bruce has been active in EEGS and SAGEEP since 1993 and is also a member of AGU, SEG, NGWA and AAPG (Bruce was recently elected VP of AAPG Division of Environmental Geosciences). Among his activities in EEGS, Bruce has served as EEGS Vice-President- Committees, as At-large Board Member and as the Inter-Society Committee Chair. In the latter position, he has been active for nearly ten years in coordinating activities of near-surface sections of other geophysical organizations with EEGS. He served as Technical Chair for the 2013 conference in Denver, organized a special session on the Edwards Aquifer for SAGEEP 2003 in San Antonio, co-chaired the 2012 workshop on Hydrofracturing, interfaced with the agricultural geophysics group, and has played an active role in developing other components of the technical program for several SAGEEPs. His most recent contribution was serving on the Task Force that considered the merger of EEGS with SEG.

Since 2002, EEGS has presented the Gold Award to recognize an individual who has made exceptional contributions to the engineering and environmental geophysics community and to EEGS. In September of 2014, EEGS lost one of its most active and loyal members, John Nicholl. To honor this man of integrity and honesty, the EEGS board voted to rename the Gold Award as the John Nicholl Memorial Award. The 2015 recipient, Dr. Bruce D. Smith, is the first to receive this award with its new designation.

COMING EVENTS AND ANNOUNCEMENTS

Message from Bruce Smith on Being the 2015 Recipient of the John Nicholl Memorial Award

I am honored to be the first recipient of this award. John was a pillar of support for EEGS over the decades that he was a member. He encouraged myself and others in service to the society and mentored our participation in its growth. Most recently John, I, and others served on a committee to evaluate a possible merger with the Society of Exploration Geophysicists. Even though the merger did not take place, the documents and ideas developed are a firm foundation for the future development of EEGS. John encouraged my activities over the years as a board of directors (BOD) member and to lead development of intersociety communication. John recognized the importance of intersociety communication and supported the development of a committee dedicated to the goal of improved communication. I have served as chair of the intersociety committee for the last few years.

I also appreciate the efforts that the BOD took to surprise me at the 2015 SAGEEP presentation. When I was given my registration material at the BOD meeting two days before the meeting, I was rather surprised that packet did not include a program. But since an electronic version of the program had been implemented I thought perhaps a cost saving move had been undertaken to limit printed programs. My wife and BOD also kept me from “stumbling” into programs. My colleagues at the USGS kept from me their participation in the award write-up. The Sunday night before the Monday presentations, I thought that I had better confirm the schedule. Finally locating a program in the registration area, I was flabbergasted to find that I was the Nichole award winner.

Last but not least, I have appreciated the support of EEGS members in personal and professional matters. Member to member communication and open governance continues to be a unique aspects of EEGS that John also fostered.

COMING EVENTS AND ANNOUNCEMENTS

EEGS Forges New Collaborations

The past year has been a busy time for EEGS. The Society's presidential duo Moe Momayez and Lee Slater (2015 and 2016 Presidents) signed four agreements that will increase the level of collaboration and support with sister societies.

In September 2014, Momayez signed a Memorandum of Understanding with the European Association of Geoscientists and Engineers (EAGE) that offers EEGS:

- Subscriptions to EAGE First Break and EAGE Newsletter
- Subscriptions to scientific journals Geophysical Prospecting, Near Surface Geophysics, Petroleum Geoscience and Basin Research (for a discounted fee)
- Prerogative to choose one lecturer per year from the 'Distinguished Lecturer Programme', who will visit EEGS to present their lecture
- Support for special and regular issues of JEEG
- Support for SAGEEP in the form of sponsorship of short courses and workshop, and promoting the near-surface geophysics annual conference.

"Closer ties with EAGE will help EEGS promote its products beyond North America," said 2015 EEGS President Moe Momayez. "I would like to recognize the efforts of Micki Allen, the EEGS-EAGE Liaison Officer during the discussions with EAGE. Her contribution helped us arrive at this equitable agreement that will benefit both societies."

In March 2015, EEGS signed a partnership agreement with Geoscientists Without Borders® (GWB), the award-winning humanitarian geoscience program of the Society of Exploration Geophysicists (SEG). This partnership provides opportunities for program growth, development and outreach to a much broader audience, enabling many more geoscientists to experience the dynamic growth and impact this program is providing all around the world. EEGS hopes that its support of GWB would lead to more ambitious projects to help those in need and impact the reputation of geophysics around the world. Geoscientists Without Borders® is changing lives globally. Today, 23 projects have been selected in 18 different countries with 8 currently active. GWB's mission, "To support humanitarian applications of geoscience around the world," provides a perfect complement to the mission of EEGS. "Over the years, Geoscientists Without Borders® has used the expertise of scientists and engineers to touch the lives of countless people internationally. "As president of EEGS, I am proud of our partnership and the support we have given this organization, and am sure they will continue to pioneer humanitarian geoscience projects across the globe," said 2015 EEGS President, Moe Momayez.

During the SAGEEP conference in Austin, TX, 2015 EEGS President Moe Momayez and John Lane, the current SEG-NSG president renewed a five-year agreement between EEGS and SEG that recognizes the mutual interests of their members, and advances the common goals and objectives of each Society. The first agreement was signed in June 2005 and committed Business Officers of both Societies to exchange announcements of technical meetings of their respective Societies. The agreement provides for the two Societies to exchange two copies of each issue of their respective journals and newsletters and news magazines; for members of the Societies to purchase publications of the other Society at the member prices of the publishing Society; and for each organization to provide a co-chair and two members for a liaison committee charged with considering and making recommendations to the respective organizations regarding other areas of cooperation, such as joint meetings, workshops, continuing education courses, and publications.

In April 2015, Lee Slater, EEGS 2016 President, executed an Alliance Agreement between EEGS and the American Geophysical Union (AGU) that promotes the following:

- The extension of benefits to members of both organizations
- The exchange of information on key programs and initiatives
- The expansion of membership of both organizations through possible joint programs
- The organization of joint meetings
- Additional educational opportunities, professional services, and student programs.

"AGU recognized the importance of environmental and engineering geophysics when it established the Near Surface Geophysics (NS) Focus Group'; this agreement with EEGS further testifies to the growing importance of geophysical studies of the near surface to the union" said Lee Slater.

Individual Membership Categories

EEGS is the premier organization for geophysics applied to engineering and environmental problems. Our multi-disciplinary blend of professionals from the private sector, academia, and government offers a unique opportunity to network with researchers, practitioners, and users of near-surface geophysical methods.

Memberships include access to the *Journal of Environmental & Engineering Geophysics (JEEG)*, proceedings archives of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), and our quarterly electronic newsletter, *FastTIMES*. Members also enjoy complimentary access to SEG's technical program expanded abstracts, discounted SAGEEP registration fees, books and other educational publications. EEGS offers a variety of membership categories tailored to fit your needs. Please select (circle) your membership category and indicate your willingness to support student members below:

☐ **Yes, I wish to sponsor _______ student(s) @ $20 each to be included in my membership payment.**

Individual Members

New this year: Individual members are invited to sponsor student members. Simply indicate the number of students you'd like to support (at $20 each) to encourage growth in this important segment of EEGS' membership.

Category	Electronic *JEEG* Available Online	Printed *JEEG* Mailed to You
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If you have not been a member of EEGS before, Welcome! We offer a reduced rate for new members to enjoy all the benefits of individual membership (except vote or hold office) for one year.

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EEGS is the premier organization for geophysics applied to engineering and environmental problems. Our multi-disciplinary blend of professionals from the private sector, academia, and government offers a unique opportunity to network with researchers, practitioners, and users of near-surface geophysical methods.

Memberships include access to the *Journal of Environmental & Engineering Geophysics (JEEG)*, proceedings archives of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), and our quarterly electronic newsletter *FastTIMES*. Members also enjoy complimentary access to SEG's technical program expanded abstracts, discounted SAGEEP registration fees, books and other educational publications. EEGS offers a variety of membership categories tailored to fit your needs. We've added value to all the Corporate Membership categories and added two new Website Advertising opportunities. We've packaged the two for an even greater value! Please select (circle) your membership category and rate. EEGS is also offering an opportunity for all EEGS members to help support student(s) at $20 each. Please indicate your willingness to contribute to support of student members below:

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Corporate Donor *Includes one (1) individual EEGS membership, one (1) full conference registration to SAGEEP, a company profile and linked logo on the EEGS Corporate Members web page, a company profile in FastTIMES and the SAGEEP program, recognition at SAGEEP and a 10% discount on advertising in JEEG and FastTIMES*	$660	$670	$1170 a $2005 value!
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	☐ UXO		☐ NSG	
	☐ Aerial Geophysics		☐ SEG	
	☐ Other		☐ SSA	
			☐ SPWLA	

1720 South Bellaire Street | Suite 110 | Denver, CO 80222-4303

(p) 001.1.303.531.7517 | (f) 000.1.303.820.3844 | staff@eegs.org | www.eegs.org

FOUNDATION CONTRIBUTIONS

FOUNDERS FUND

The Founders Fund has been established to support costs associated with the establishment and maintenance of the EEGS Foundation as we solicit support from larger sponsors. These will support business office expenses, necessary travel, and similar expenses. It is expected that the operating capital for the foundation will eventually be derived from outside sources, but the Founder's Fund will provide an operation budget to "jump start" the work. Donations of $50.00 or more are greatly appreciated. For additional information about the EEGS Foundation (an IRS status 501(c)(3) tax exempt public charity), visit the website at http://www.EEGSFoundation.org.

Foundation Fund Total: $ ________________

STUDENT SUPPORT ENDOWMENT

This Endowed Fund will be used to support travel and reduced membership fees so that we can attract greater involvement from our student members. Student members are the lifeblood of our society, and our support can lead to a lifetime of involvement and leadership in the near-surface geophysics community. Donations of $50.00 or more are greatly appreciated. For additional information about the EEGS Foundation (a tax exempt public charity), visit the website at http://www.EEGSFoundation.org.

Student Support Endowment Total: $ ________________

CORPORATE CONTRIBUTIONS

The EEGS Foundation is designed to solicit support from individuals and corporate entities that are not currently corporate members (as listed above). We recognize that most of our corporate members are small businesses with limited resources, and that their contributions to professional societies are distributed among several organizations. The Corporate Founder's Fund has been developed to allow our corporate members to support the establishment of the Foundation as we solicit support from new contributors.

Corporate Contribution Total: $ ________________

Foundation Total: $ ________________

PAYMENT INFORMATION

- ☐ **Check/Money Order**
- ☐ **VISA**
- ☐ **MasterCard**
- ☐ **AmEx**
- ☐ **Discover**

Subtotals

Membership: $ ________________

Student Sponsorship: $ ________________

Foundation Contributions: $ ________________

Grand Total: $ ________________

Card Number **Exp. Date**

Name on Card

Signature

Make your check or money order in US dollars payable to: EEGS. Checks from Canadian bank accounts must be drawn on banks with US affiliations (example: checks from Canadian Credit Suisse banks are payable through Credit Suisse New York, USA). Checks must be drawn on US banks.

Payments are not tax deductible as charitable contributions although they may be deductible as a business expense. Consult your tax advisor.

Return this form with payment to: EEGS, 1720 South Bellaire Street, Suite 110, Denver, CO 80222 USA
Credit card payments can be faxed to EEGS at 001.1.303.820.3844

Corporate dues payments, once paid, are non-refundable. Individual dues are non-refundable except in cases of extreme hardship and will be considered on a case-by-case basis by the EEGS Board of Directors. Requests for refunds must be submitted in writing to the EEGS business office.

QUESTIONS? CALL 001.1.303.531.7517

EEGS CORPORATE MEMBERS

Corporate Benefactor

Your Company Here!

Corporate Associate

Advanced Geosciences, Inc.
www.agiusa.com

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www.cgg.com

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Geogiga Technology Corporation
www.geogiga.com

Geomar Software Inc.
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www.geonics.com

Geophysical Survey Systems, Inc.
www.geophysical.com

Geosoft Inc.
www.geosoft.com

Geostuff
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www.geovista.co.uk

Interpex Ltd.
www.interpex.com

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www.mountsopris.com

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www.rtclark.com

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www.northwestgeophysics.com

Quality Geosciences Company, LLC
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Spotlight Geophysical Services
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Corporate Student Sponsor

Geo Solutions Limited, Inc.
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Spotlight Geophysical Services
www.spotlightgeo.com

EEGS STORE

Environmental and Engineering Geophysical Society

2015 Publications Order Form

ALL ORDERS ARE PREPAY

1720 S. Bellaire Street, Suite 110
Denver, CO 80222-4303
Phone: 303.531.7517; Fax: 303.820.3844
E-mail: staff@eegs.org; Web Site: www.eegs.org

Sold To:

Name: ______________________

Company: ______________________

Address: ______________________

City/State/Zip: ______________________

Country: ______________ Phone: __________

E-mail: ______________ Fax: __________

Ship To (If different from "Sold To":

Name: ______________________

Company: ______________________

Address: ______________________

City/State/Zip: ______________________

Country: ______________ Phone: __________

E-mail: ______________ Fax: __________

Instructions: Please complete both pages of this order form and fax or mail the form to the EEGS office listed above. Payment must accompany the form or materials will not be shipped. Faxing a copy of a check does not constitute payment and the order will be held until payment is received. Purchase orders will be held until payment is received. If you have questions regarding any of the items, please contact the EEGS Office. Thank you for your order!

SAGEEP PROCEEDINGS

			Member	Non-Member
	0036	2014 (CD-ROM)	$75	$100
	0034	2013 (CD-ROM)	$75	$100
	0033	2012 (CD-ROM)	$75	$100
	0030	2011 (CD-ROM)	$75	$100
	0029	2010 (CD-ROM)	$75	$100
	0026	2009 (CD-ROM)	$75	$100
	0025	2008 (CD-ROM)	$75	$100
	0023	2007 (CD-ROM)	$75	$100

			Member	Non-Member
	0020	2006 (CD-ROM)	$75	$100
	0018	2005 (CD-ROM)	$75	$100
	0016	2004 (CD-ROM)	$75	$100
	0015	2003 (CD-ROM)	$75	$100
	0014	2002 (CD-ROM)	$75	$100
	0013	2001 (CD-ROM)	$75	$100
	0012	1988-2000 (CD-ROM)	$150	$225
	SUBTOTAL—PROCEEDINGS ORDERED:			

SAGEEP Short Course Handbooks

	0039	2013 Agricultural Geophysics: Methods Employed and Recent Applications - Barry Allred, Bruce Smith, et al.	$35	$45
	0038	2010 Processing Seismic Refraction Tomography Data (including CD-ROM) - William Doll	$35	$45
	0037	2011 Application of Time Domain Electromagnetics to Ground-water Studies – David V. Fitterman	$20	$30
	0032	2010 Application of Time Domain Electromagnetics to Ground-water Studies – David V. Fitterman	$20	$30
	0027	2010 Principles and Applications of Seismic Refraction Tomography (Printed Course Notes & CD-ROM) - William Doll	$70	$90
	0028	2009 Principles and Applications of Seismic Refraction Tomography (CD-ROM w/ PDF format Course Notes) - William Doll	$70	$90
	0007	2002 - UXO 101 - An Introduction to Unexploded Ordnance - (Dwain Butler, Roger Young, William Veith)	$15	$25
	0009	2001 - Applications of Geophysics in Geotechnical and Environmental Engineering (HANDBOOK ONLY) - John Greenhouse	$25	$35
	0011	2001 - Applications of Geophysics in Environmental Investigations (CD-ROM ONLY) - John Greenhouse	$80	$105
	0010	2001- Applications of Geophysics in Geotechnical and Environmental Engineering (HANDBOOK) & Applications of Geophysics in Environmental Investigations (CD-ROM) - John Greenhouse	$100	$125
	0004	1998 - Global Positioning System (GPS): Theory and Practice - John D. Bossler & Dorota A. Brzezinska	$10	$15
	0003	1998 - Introduction to Environmental & Engineering Geophysics - Roelof Versteeg	$10	$15
	0002	1998 - Near Surface Seismology - Don Steeples	$10	$15
	0001	1998 - Nondestructive Testing (NDT) - Larry Olson	$10	$15
	0005	1997 - An Introduction to Near-Surface and Environmental Geophysical Methods and Applications - Roelof Versteeg	$10	$15
	0006	1996 - Introduction to Geophysical Techniques and their Applications for Engineers and Project Managers - Richard Benson & Lynn Yuhr	$10	$15

Miscellaneous Items

	0031	***New Pricing!!*** Advances in Near-surface Seismology and Ground Penetrating Radar—R. Miller, J.Bradford, K.Holliger Special Pricing Available for Limited Time—through March 25, 2015—end of SAGEEP 2015!	$79	$99
	0021	Geophysics Applied to Contaminant Studies: Papers Presented at SAGEEP from 1988-2006 (CD-ROM)	$50	$75
	0022	Application of Geophysical Methods to Engineering and Environmental Problems - Produced by SEGJ	$35	$45
	0019	Near Surface Geophysics - 2005 Dwain K. Butler, Ed.; Hardcover Special student rate - $71.20	$89	$139
	0035	Einstein Redux: A Humorous & Refreshing New Chapter in the Einstein Saga—D.Butler	$20	$25

MISCELLANEOUS ITEMS CONTINUED ON NEXT PAGE...

EEGS STORE

Publications Order Form (Page Two)

		EEGS T-shirt (X-Large) Please circle: white/gray	$10	$10
		EEGS Lapel Pin	$3	$3
		SUBTOTAL—SHORT COURSE/MISC. ORDERED ITEMS:		

Journal of Environmental and Engineering Geophysics **(JEEG) Back Issue Order Information:**
Member Rate: $15 | Non-Member Rate: $25

Qt.	Year	Issue	Qt.	Year	Issue	Qt.	Year	Issue
	1995	JEEG 0/1 - July		**2004**	JEEG 9/1- March		**2009**	JEEG 14/1 - March
		JEEG 0/2 - January			JEEG 9/2 - June			JEEG 14/2 - June
	1996	JEEG 1/1 - April			JEEG 9/3 - September			JEEG 14/3 - September
		JEEG 1/2 - August			JEEG 9/4 - December			JEEG 14/4 - December
		JEEG 1/3 - December		**2005**	JEEG 10/1 - March		**2010**	JEEG 15/1 - March
	1998	JEEG 3/2 - June			JEEG 10/2 - June			JEEG 15/2 - June
		JEEG 3/3 - September			JEEG 10/3 - September			JEEG 15/3 - September
		JEEG 3/4 - December			JEEG 10/4 - December			JEEG 15/4 - December
	1999	JEEG 4/1 – March		**2006**	JEEG 11/1 - March		**2011**	JEEG 16/1 - March
		JEEG 4/2 - June			JEEG 11/2 - June			JEEG 16/2 - June
		JEEG 4/3 - September			JEEG 11/3 - September			JEEG 16/3 - September
		JEEG 4/4 - December			JEEG 11/4 - December			JEEG 16/4 - December
	2000	JEEG 5/3 - September		**2007**	JEEG 12/1 - March		**2012**	JEEG 17/1 - March
		JEEG 5/4 - December			JEEG 12/2 - June			JEEG 17/2 - June
	2001	JEEG 6/1 - March			JEEG 12/3 - September			JEEG 17/3 - September
		JEEG 6/3 - September			JEEG 12/4 - December			JEEG 17/4 - December
		JEEG 6/4 - December		**2008**	JEEG 13/1 - March		**2013**	JEEG 18/1 - March
	2003	JEEG 8/1- March			JEEG 13/2 - June			JEEG 18/2 - June
		JEEG 8/2 - June			JEEG 13/3 - September			JEEG 18/3 - September
		JEEG 8/3 - September			JEEG 13/4 - December			JEEG 18/4 - December
		JEEG 8/4 - December					**2014**	JEEG 19/1 - March
								JEEG 19/2 - June
					SUBTOTAL—JEEG ISSUES ORDERED			

SUBTOTAL - SAGEEP PROCEEDINGS ORDERED	
SUBTOTAL - SHORT COURSE / MISCELLANEOUS ITEMS ORDERED	
SUBTOTAL - JEEG ISSUES ORDERED	
CITY & STATE SALES TAX (If order will be delivered in the Denver, Colorado—add an additional 7.62%)	
SHIPPING & HANDLING (US—$10; Canada/Mexico—$20; All other countries: $45)	
GRAND TOTAL:	

Order Return Policy: Returns for credit must be accompanied by invoice or invoice information (invoice number, date, and purchase price). Materials must be in saleable condition. Out-of-print titles are not accepted 180 days after order. No returns will be accepted for credit that were not purchased directly from EEGS. Return shipment costs will be borne by the shipper. Returned orders carry a 10% restocking fee to cover administrative costs unless waived by EEGS.

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☐ Check #: ________________________________ (Payable to EEGS)

☐ Purchase Order: ________________________________
(Shipment will be made upon receipt of payment.)

☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover

Card Number: ______________________________ CVV# _____
Exp. Date: ____

Cardholder Name (Print) ____________________________________
Signature: ____

Important Payment Information: Checks from Canadian bank accounts must be drawn on banks with US affiliations (example: checks from Canadian Credit Sulsse banks are payable through Credit Sulsse New York, USA). If you are unsure, please contact your bank. As an alternative to paying by check, we recommend sending money orders or paying by credit card.

EEGS STORE

Environmental and Engineering Geophysical Society

1720 S. Bellaire Street, Suite 110
Denver, CO 80222-4303
Phone: 303.531.7517
Fax: 303.820.3844
E-mail: staff@eegs.org
Web Site: www.eegs.org

2015 Merchandise Order Form

ALL ORDERS ARE PREPAY

Sold To:

Name: ____
Company: ____
Address: ____
City/State/Zip: ____________________________________
Country: _____________________ Phone: ______________
E-mail: ______________________ Fax: ________________

Ship To (If different from "Sold To"):

Name: ____
Company: ____
Address: ____
City/State/Zip: ____________________________________
Country: __________________ Phone: ____________
E-mail: ____________________ Fax: ______________

Instructions: Please complete this order form and fax or mail the form to the EEGS office listed above. Payment must accompany the form or materials will not be shipped. Faxing a copy of a check does not constitute payment and the order will be held until payment is received. Purchase orders will be held until payment is received. If you have questions regarding any of the items, please contact the EEGS Office. Thank you for your order!

Merchandise Order Information:

ITEM DESCRIPTION	QTY	EEGS T-SHIRT COLOR WHITE OR GRAY	MEMBER RATE	NON-MEMBER RATE	TOTAL
EEGS Mug			$10	$10	
SAGEEP 2015 T-shirt (Small)			$18	$18	
SAGEEP 2015 T-shirt (Medium)			$18	$18	
SAGEEP 2015 T-shirt (Large)			$18	$18	
SAGEEP 2015 T-shirt (XLarge)			$18	$18	
SAGEEP 2015 T-shirt (XXLarge)			$18	$18	
EEGS T-shirt (XLarge)			$10	$10	
EEGS Lapel Pin			$3	$3	
SUBTOTAL – MERCHANDISE ORDERED:					

TOTAL ORDER:

SUBTOTAL – Merchandise Ordered:	
STATE SALES TAX: (If order will be delivered in Colorado – add 3.7000%):	
CITY SALES TAX: (If order will be delivered in the City of Denver – add an additional 3.5000%):	
SHIPPING AND HANDLING (US - $7; Canada/Mexico - $15; All other countries - $40):	
GRAND TOTAL:	

Payment Information:

☐ Check #: ______________________ (Payable to EEGS)

☐ Purchase Order: ______________________
(Shipment will be made upon receipt of payment.)

☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover

Card Number: _______________________CVV# ____ Cardholder Name (Print): ___________________________

Exp. Date: __________________________ Signature: _______________________________________

Three easy ways to order:
Fax to: 303.820.3844
Internet: www.eegs.org
Mail to: EEGS
1720 S. Bellaire St., #110
Denver, CO 80222-4303

THANK YOU FOR YOUR ORDER!

Order Return Policy: Returns for credit must be accompanied by invoice or invoice information (invoice number, date, and purchase price). Materials must be in saleable condition. Out-of-print titles are not accepted 180 days after order. No returns for credit will be accepted which were not purchased directly from EEGS. Return shipment costs will be borne by the shipper. Returned orders carry a 10% restocking fee to cover administrative costs unless waived by EEGS.

EEGS STORE

Environmental and Engineering Geophysical Society

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Denver, CO 80222-4303
Phone: 303.531.7517
Fax: 303.820.3844
E-mail: staff@eegs.org
Web Site: www.eegs.org

2015 SAGEEP T-SHIRTS Order Form

ALL ORDERS ARE PREPAY

Sold To:

Name: ______________________________
Company: ______________________________
Address: ______________________________
City/State/Zip: ______________________________
Country: ______________ Phone: ______________
E-mail: ______________ Fax: ______________

Ship To (If different from "Sold To")**:**

Name: ______________________________
Company: ______________________________
Address: ______________________________
City/State/Zip: ______________________________
Country: ______________ Phone: ______________
E-mail: ______________ Fax: ______________

Instructions:
T-Shirts can be picked up at SAGEEP 2015! Please complete this order form and fax or mail to the EEGS office listed above. Payment must accompany the form or materials will not be shipped. If you wish to pick your order up on site in Austin, TX, mark your form with a check in the space below. **If you will be picking up your T-Shirt(s) at SAGEEP, do not include tax or shipping and handling** – listed prices are inclusive of all fees. Faxing a copy of a check does not constitute payment and the order will be held until payment is received. Purchase orders will be held until payment is received. If you have questions regarding any of the items, please contact the EEGS Office. Thank you for your order!

SAGEEP 2015 T-Shirt Order Information:

ITEM DESCRIPTION	QTY	ONE COLOR/ BLUE	MEMBER NON-MEMBER RATE	PICK UP AT SAGEEP (CHECK)	TOTAL
SAGEEP 2015 T-Shirts – Sizing Chart Available online (http://www.eegs.org/program)					
SAGEEP 2015 T-Shirt (Small)			$18		
SAGEEP 2015 T-Shirt (Medium)			$18		
SAGEEP 2015 T-Shirt (Large)			$18		
SAGEEP 2015 T-Shirt (X-Large)			$18		
SAGEEP 2015 T-Shirt (XX-Large)			$18		

SUBTOTAL –

TOTAL ORDER:

SUBTOTAL – Merchandise Ordered:	
STATE SALES TAX: (If order will be delivered in Colorado – add 3.7000%):	
CITY SALES TAX: (If order will be delivered in the City of Denver – add an additional 3.5000%):	
SHIPPING AND HANDLING (US - $7; Canada/Mexico - $15; All other countries - $40):	

GRAND TOTAL:

Payment Information:

☐ Check #: ______________ (Payable to EEGS)
☐ Purchase Order: ______________
(Shipment will be made upon receipt of payment.)

☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover

Three easy ways to order:
Fax to: 303.820.3844
Internet: www.eegs.org
Mail to: EEGS
1720 S. Bellaire St., #110
Denver, CO 80222-4303

Card Number: ______________ Cardholder Name (Print): ______________

Exp. Date: ______________ CVV#______ Signature: ______________

THANK YOU FOR YOUR ORDER!

Order Return Policy: Returns for credit must be accompanied by invoice or invoice information (invoice number, date, and purchase price). Materials must be in saleable condition. Out-of-print titles are not accepted 180 days after order. No returns for credit will be accepted which were not purchased directly from EEGS. Return shipment costs will be borne by the shipper. Returned orders carry a 10% restocking fee to cover administrative costs unless waived by EEGS.