FastTIMES

September 2008
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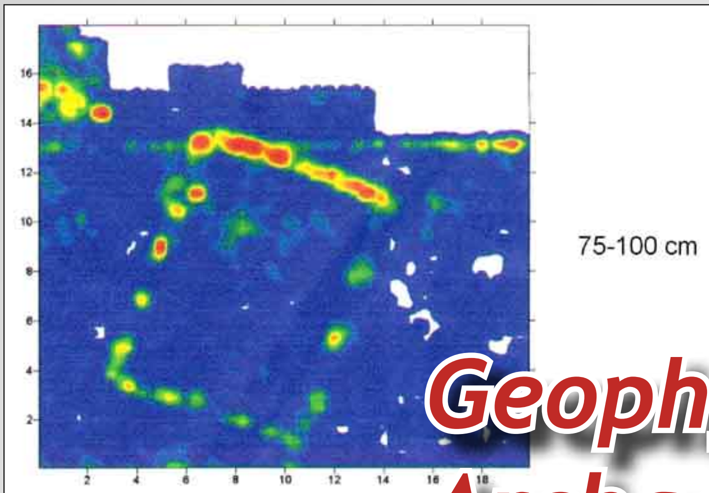
News for the Near-Surface Geophysical Sciences

Published by the Environmental & Engineering Geophysical Society

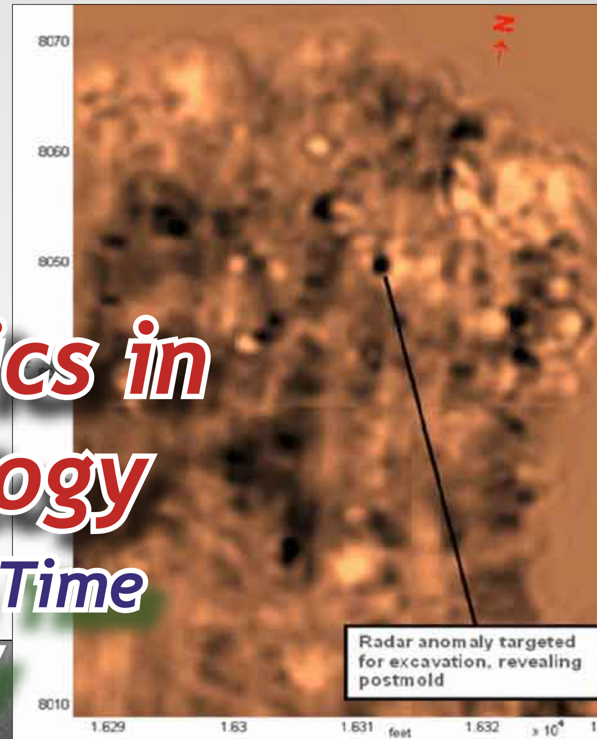
Geophysics in Archaeology

Looking Back in Time with Technology



GPR depth slicing

Radar tomography shows post molds



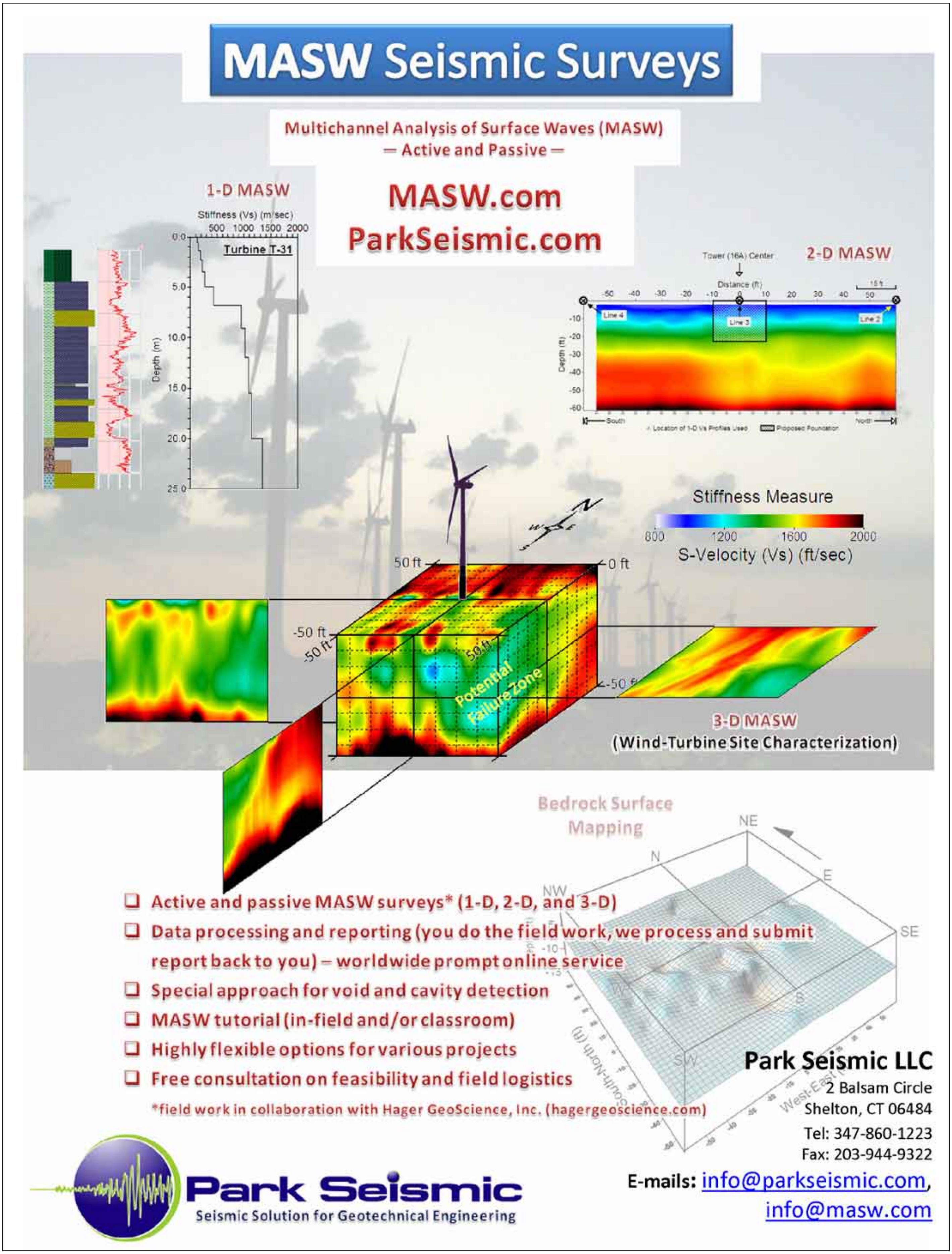
GPR at a Mayan pyramid

Magnetic gradients reveal earthwork complexes

Also in this issue . . .

- Best of SAGEEP 2008 to Krakow
- EEGS/SEG Workshop on Induced Polarization at SEG 2008, Las Vegas
- Nominations Open for EEGS Board and 2009 Early Career Award
- AGU Near Surface Focus Group Enters Second Term

New: Magnetic viscosity meter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On the Cover

Near-surface geophysics has found wide application in archaeology, the focus of this issue of ***FastTIMES*. Upper left:** GPR depth slice at a Roman temple (article by L. Conyers on p. 29); **Lower left:** Rob Stewart on a Mayan pyramid (article by M. Allen and R. Stewart on p. 36); **Lower right:** Magnetic gradiometry reveals ancient earthworks in Ohio (article by J. Burks, p. 51); **Upper right:** Post molds in radar tomographic images taken near the Manatee River, Florida (article by R. Birken and others, p. 42). **Bottom right**: New magnetic viscosity meter for borehole and surface use (article by D. Lynch on p. 25).

What We Want From You

The ***FastTIMES*** editors appreciate most any geophysical contribution. Suggestions for the December 2008 issue include humanitarian geophysics and cavity and tunnel detection. We also welcome photographs and brief noncommercial 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 ***FastTIMES*** editorial team by November 21, 2008 to ensure inclusion in the next issue.

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Contents

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FastTIMES

FastTIMES 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 this 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 ***FastTIMES***, our society newsletter, and (4) establishing and 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 currently $90 for an individual membership, $50 for a student membership with a ***JEEG*** subscription ($20 without ***JEEG)***, and $650 to $3750 for various levels of corporate membership. The membership application is available at the back of this issue, from the EEGS office at the address given below, or online at *www.eegs.org*. See the back for an explanation of membership categories.

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To advertise in ***FastTIMES***, contact:

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(303) 531-7517

The next ***FastTIMES*** will be published in December 2008. Please send articles to a member of the editorial team by November 21. Advertisements are due to Jackie Jacoby by November 21.

Calendar

*Please send additions, errors, and omissions to a member of the **FastTIMES** editorial team.*

2008

October 3	SAGEEP 2009 abstract deadline
October 5–9	2008 Joint Meeting of The Geological Society of America, Houston, Texas
October 20–23	24th Annual International Conference on Soils, Sediment, and Water, Amherst, Massachusetts
November 9–14	SEG International Exposition and 78th Annual Meeting, Las Vegas, Nevada
November 14	EEGS/SEG Induced Polarization Workshop, Las Vegas, Nevada
December 1–4	2008 Highway Geophysics–NDE Conference, Charlotte, North Carolina
December 2–5	NGWA Ground Water Expo and Annual Meeting, Las Vegas, Nevada
December 12	SAGEEP 2009 full papers due and Student Poster Session abstracts due
December 15–19	AGU Fall Meeting, San Francisco, California

2009

February 22–25	ASEG 09: 20th Conference and Exhibition, Australian Society of Exploration Geophysicists, Adelaide, South Australia
March 15–19	International Foundation Congress and Equipment Exhibition, Lake Buena Vista, Florida
March 29–April 2	22nd SAGEEP, Fort Worth, Texas
April 19–23	NGWA 2009 Ground Water Summit, Tucson, Arizona
May 24–27	2009 Joint Assembly, Toronto, Ontario, Canada
September 7–9	Near Surface 2009: 15th European Meeting of Environmental and Engineering Geophysics, Dublin, Ireland

Notes from EEGS

President's Message

Jonathan Nyquist, President (nyq@temple.edu)

Editor's Note: Bill Brown, who began serving as EEGS President in April, resigned his position effective September 5 to devote more time to family and career. On September 9, the EEGS Board of Directors selected Jonathan Nyquist, who was serving as President Elect, to fill out Bill's unfinished year. Jon will continue as President until his term expires in April 2010. The EEGS Board members express their deep appreciation for the time and energy Bill expended for EEGS. Best wishes, Bill!

It is the duty of every president to encourage new members to join his or her society. Assuming this responsibility has led me to reflect on the benefits of being in EEGS. Ours is a small society compared with giants such as the American Geophysical Union (AGU), the Geological Society of America (GSA), or the Society of Exploration Geophysicists (SEG). So what does it mean to be an EEGS member? EEGS membership means access to ***JEEG***, a top-quality scientific journal, and our popular newsletter ***FastTimes***. Soon it will grant electronic access to the EEGS Research Collection (***JEEG*** and SAGEEP papers) in SEG's Digital Library as well.

EEGS membership means attending SAGEEP, which has been the premier meeting on near-surface geophysics for over 20 years. I attended my first SAGEEP in 1987, shortly after I graduated from the University of Wisconsin, and have not missed a one since. No other symposium brings together such a diverse collection of geophysicists and engineers, academics and practitioners, students and veterans. I always come away invigorated with new ideas for research, new methods to try in the field, and new ways to process and visualize data. And as an EEGS member I receive a registration discount at SAGEEP that more than covers my membership dues!

EEGS membership means professional fellowship. Being an avid reader and addicted to gizmos, I recently purchased one (okay, two) of Amazon's electronic book readers, the Kindle. One of the experimental features offered Kindle owners is "NowNow." You can type in any question you like and a team at Amazon will research an answer and download it to your e-reader within minutes. EEGS has always been my geophysical NowNow. The collective knowledge and experience our society encompasses is amazing.

Scholarship, new ideas, and professional fellowship: these are the reasons I have renewed my membership year after year for some 15 years. These are the reasons I have encouraged my students to become EEGS members. As incoming president, I encourage you to talk with your own students, colleagues, customers, and associates about the benefits of being an EEGS member. See if you can get them to come to SAGEEP 2009 in Fort Worth, Texas. One meeting was all it took to get me hooked!


Exploring the World
Choosing the Right Magnetometer
Magnetic applications in near surface geophysics are broad: mineral exploration, archaeology, environmental & engineering, geological hazards, UXO detection. It is important to choose the right solution.
The Versatility of Overhauser
For general work and teaching the Overhauser instrument is ideal: low power consumption, 5 Hz sampling, no directional errors, optional sensitivity 0.015 nT @ 1 Hz. Overhauser is made for efficiency with its light weight, low power consumption, robust console and intelligent surveying options.
The Power of Potassium
For sensitive work and research the ultimate solution is the Potassium instrument. The K-Mag samples at a leading 20 Hz for acquisition of high resolution results, sensitivity 0.0007 nT/√Hz (70mm cell). It features minimal directional errors and high gradient tolerance for culturally "noisy" projects.
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From the FastTIMES Editorial Team

FastTIMES is distributed as an electronic document (pdf) to all EEGS members, is sent by web link to several related professional societies, and is available to all for free download from the EEGS web site at *www.eegs.org/fasttimes/latest_issue.cfm*. The most recent issue (July 2008, cover image below) was downloaded more than 9000 times through August, and past issues of ***FastTIMES*** 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 ***FastTIMES*** 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. Contact a member of the editorial team to discuss your ideas!

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Roger Young *(ryoung@ou.edu)*

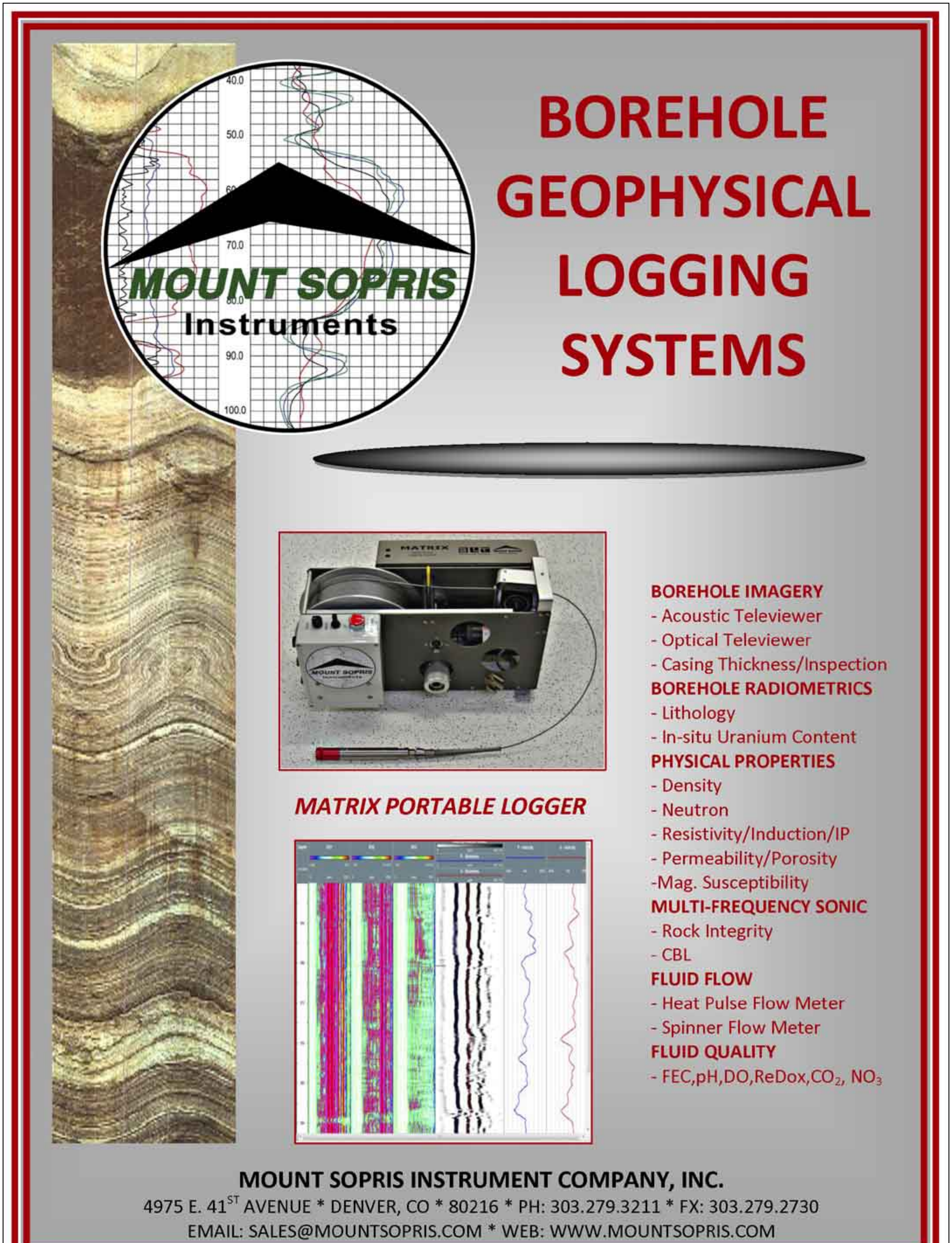
Brad Isbell *(bisbell@hgiworld.com)*

EEGS Board Nominations Now Open

Nomination Deadline: November 30, 2008

EEGS is soliciting nominations for the 2009–2010 Board of Directors, including the positions of President Elect, Vice President Elect (SAGEEP), Vice President Elect (Committees), and three Member-at-Large vacancies. You may nominate yourself or others. Nominees must be EEGS members. Please send your nominations to Jeffrey Paine at *jeff.paine@beg.utexas.edu*.

Elections will be held in January 2009 for terms that will begin at SAGEEP 2009 in Fort Worth, Texas in late March. A photograph, brief biography, and platform statement for each candidate will be distributed with the ballot.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2009 EEGS Membership Renewal Period Beginning

Be sure to renew your EEGS membership for 2009! In addition to the more tangible member benefits (including a print subscription to ***JEEG***, ***FastTIMES*** 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 the functionality of our web site to enable desired capabilities such as membership services, publication ordering, and search and delivery of SAGEEP papers. Please watch for the renewal notices arriving by mail and email and renew promptly! As always, members can renew by mail or fax. In addition, EEGS has implemented an online renewal system. Visit *www.eegs.org* to take advantage of this capability.

Sponsorship Opportunities

There are always sponsorship opportunities available for government agencies, corporations, and individuals who wish to help support EEGS's activities. Two specific opportunities are listed below.

Online Delivery of SAGEEP Papers

EEGS already has one founding sponsor (Exploration Instruments) supporting development of an online delivery system to enable SAGEEP papers to be served from the EEGS web site. We are seeking additional sponsors to support maintenance and annual updates. Contact Jeffrey G. Paine (*jeff.paine@beg.utexas.edu*) if you are interested.

SAGEEP 2009 Sponsorship

SAGEEP is heading to Fort Worth,Texas for 2009. SAGEEP would not be possible without the generous support of government and industry sponsors. Sponsorship opportunities for 2009 are available at all levels, including general conference, individual session, icebreaker, conference bag, speaker and session chair gifts, and the Environmental & Engineering Geophysical University sessions. Contact Micki Allen (*mickiallen@marac.com*; 905-474-9118) for more information.

Savings on Auto/Homeowner Insurance for EEGS Members

EEGS' GeoCare Benefits Insurance Program has teamed up with Liberty Mutual to offer members Group Savings Plus™ — a program that provides savings on auto and homeowner insurance. Liberty Mutual also offers personal umbrella liability insurance, renters insurance, condo insurance, and boat, RV and motorcycle insurance.

With Group Savings Plus, members enjoy competitive rates on auto and home insurance based on a savings system including education, age, driver background, and auto equipment. The average group member savings on auto insurance is $327.96* per year. Auto rates are guaranteed for 12 months and automatic monthly payment is offered with no finance charges.

Members may obtain information about the Liberty Mutual plans from a national call center, the Internet, or a local service office:

1. *Call Centers: The EEGS GeoCare toll-free number is (800) 789-6419. Call centers are staffed Monday through Friday from 7 a.m. to 11 p.m. and Saturday from 7 a.m. to 9:30 p.m. (ET).*
2. *Internet Quotes: Quotes and coverage can be accessed on-line 24/7. For access go to www.geocarebenefits.com/EEGS-autohome.asp.*
3. *Local Office: A member can be connected to the nearest Liberty Mutual office (during local business hours) by calling (800) 225-8281. The call will be transferred according to the member's requested zip code.*

Rates are the same, regardless which option is used. For maximum savings, mention your EEGS membership or EEGS' client number (#112949).

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General questions regarding this Program may be directed to the GeoCare Benefits Broker's Office at 800-254-4788.

* *Figure based on a February 2008 sample of auto policyholder savings when comparing their former premium with those of Liberty Mutual's group auto and home program. Individual premiums and savings will vary.*

Best of SAGEEP 2008 to Krakow, Poland for EAGE's Near Surface 2008 Conference

For the past several years, SAGEEP and the European Meeting of Environmental and Engineering Geophysics have been exchanging "best papers" to recognize excellence and promote international cooperation. This year, four SAGEEP 2008 presenters were invited to give their papers at Near Surface 2008: the 14th European Meeting of Environmental and Engineering Geophysics, held in Krakow, Poland on September 15–17.

The SAGEEP 2008 "best paper" selection process included tabulating reviews from audience members and session chairs and evaluating the full papers in the proceedings volume. EEGS board members Doug LaBrecque and Jennifer Holt oversaw the review process, while international liaison Micki Allen made all arrangements with chosen presenters and the European meeting organizers.

The titles and authors of the four "Best of SAGEEP" papers presented in Krakow are:

Data resolution matrix and model resolution matrix of Rayleigh-wave inversion using a damped least-square method: *Jianghai Xia (Kansas Geological Survey), Richard D. Miller (Kansas Geological Survey), and Yixian Xu (Open Laboratory of Engineering Geophysics, China Department of Land and Resources)*

Estimation of bedrock depth using the horizontal-to-vertical (H/V) ambient-noise seismic method: *John W. Lane, Jr., Eric A. White, Gregory V. Steele, and James C. Cannia (all at the U. S. Geological Survey)*

Repeatability of towed magnetic data for archaeological prospection within a sand and gravel mineral deposit: *Jennifer S. Upwood (Geomatrix Earth Science Ltd), Christopher Leech (Geomatrix Earth Science Ltd.), Ian A. Hill, (University of Leicester), and Neil Linford (English Heritage)*

Modeling the EMI decay response of medium and large UXO with conventional and B-field sensors: *Michael W. Asten (Flagstaff GeoConsultants) and Andrew C. Duncan (EMIT Pty Ltd.)*

During the selection process, the reviewers identified papers judged as belonging in the top ten of SAGEEP 2008. The titles and authors of the remaining six papers were:

Imaging dispersion of passive surface waves with active scheme: *Choon B. Park (Park Seismic, LLC)*

Azimuthal self potential signatures associated with pneumatic fracturing: *DeBonne Wishart (Rutgers University), Lee Slater (Rutgers University), Deborah Schnell (Pneumatic Fracturing Inc.), and Gregory Herman (New Jersey Geological Survey)*

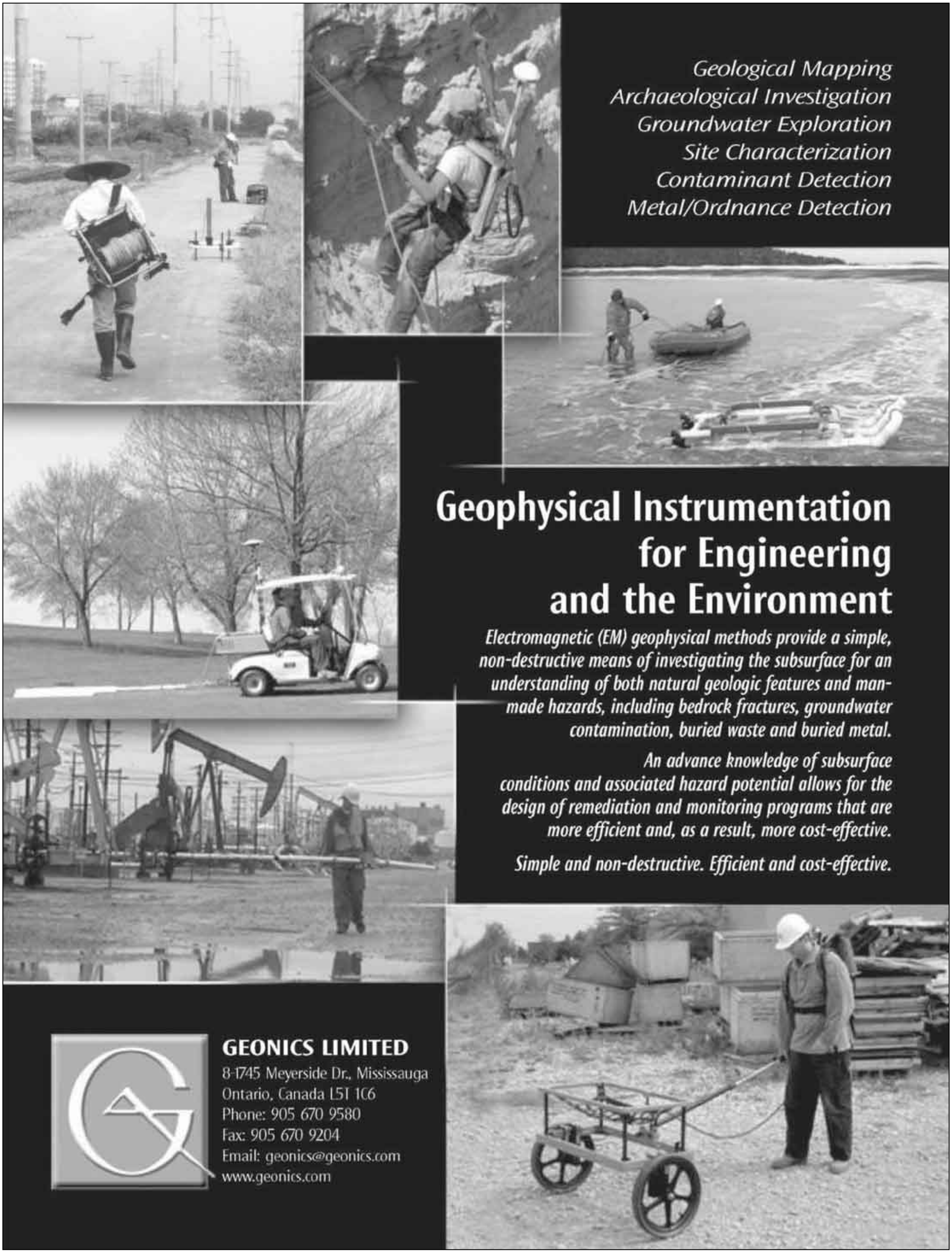
Engineering geophysics in Australia: urban case studies from Downunder: *Robert J. Whiteley and Simon B. Stewart (Coffey Geotechnics Pty Ltd.)*

Multi-faceted geophysical characterization of limestone terrains: *Tristan W. Campbell (Geoforce)*

Geophysical characterization of a levee with DC resistivity and electromagnetic measurements: *Theodore H. Asch, Maryla Deszcz-Pan, Bethany Burton, Lyndsay Ball, Wade Kress, Joseph Vrabel (all at U. S. Geological Survey), and Lewis E. Hunter (U. S. Army Corps of Engineers)*

Submarine slides at Finneidfjord (Norway): geophysical investigations: *Isabelle Lecomte (ICG/NORSAR), Maksim Bano (EOST), Svein-Erik Hamran (UiO), Einar Dalsegg (NGU), Karl-Magnus Nielsen (UiO), Marianne Holst Nielsen, (UiO), Guilhem Douillet (EOST), Emanuelle Frery (EOST), Alexandra Guy (EOST), and Shana Volesky (Vassar College)*

Congratulations to all the authors whose papers who made the top-ten list, and especially to those four (Jianghai Xia, John Lane, Jennifer Upwood, and Michael Asten) who represented SAGEEP in Krakow!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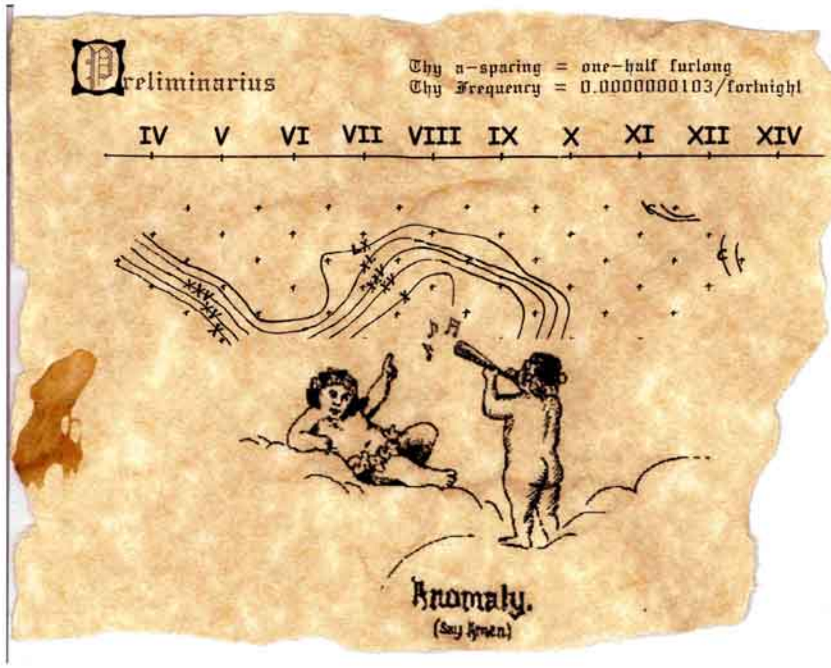
Decaying Transients

by Norman Carlson (norm@zonge.us)
Zonge Engineering and Research Organization, Tucson, Arizona

A Geophysical History Note



Early 12th century dipole-dipole resistivity pseudosection: the oldest known geophysical data plot ever discovered. This plot and two others were part of a preliminary report discovered in an undisclosed cave in Germany, hidden in a wine cask and sealed with wax. Despite extensive searching, no final report has yet been uncovered among the numerous other documents found in the wine cask.

The JEEG Pages

*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.*

Contents of the September UXO Special Issue

Journal of Environmental & Engineering Geophysics
v. 13, no. 3, September 2008

Editor's Scratch

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The September UXO Special Issue of JEEG was edited by José L. Llopis of the U. S. Army Engineer Research and Development Center in Vicksburg, Mississippi (Jose.L.Llopis@usace.army.mil). His full introduction is published in the journal. An excerpt:

> *"There have been many advances in UXO detection and discrimination capabilities since 1994, however there is still much room for improvement. High false alarm rates still plague UXO cleanup personnel and several of the papers in this issue describe some of the latest advancements in improving this subject. I would like to thank all the authors for submitting manuscripts to make this issue possible. I would also like to express my gratitude to the reviewers for offering their invaluable time and helpful technical input. I also thank Janet Simms for her help in making this Special Issue possible. Funding for the publication for this Special Issue was provided by the Strategic Environmental Research and Development Program/Environmental Security Technology Certification Program (SERDP/ESTCP), and I would like to thank Jeffrey Marqusee for his support.*

EAGE's Near Surface Geophysics Journal, October 2008

As a courtesy to EAGE and the readers of ***FastTIMES****, we reproduce the table of contents from the October issue of EAGE's* ***Near Surface Geophysics*** *journal. The journal is the continuation of the* ***European Journal of Environmental and Engineering Geophysics*** *published by the former Environmental and Engineering Geophysical Society — European Section.*

ALSO INTERESTING

Near Surface Geophysics

Volume 6 · Number 5 · October 2008

Content

Special Section on the Application of Geophysics in Agriculture Part I

Regular articles

EAGE
EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

New Tools

*New tools, whatever the source, are one of the key ingredients to innovation in near-surface applications of geophysics. We continually solicit contributions describing new tools with near-surface promise and have highlighted several instruments in the last few issues. These entries are commonly written by representatives of companies that make or market the tools and have been only lightly edited. Of course, these descriptions are provided as a professional courtesy only and neither the **FastTIMES** editors nor EEGS have verified the information presented herein. The **FastTIMES** editors welcome new submittals, to be considered for publication in **FastTIMES** as space is available. We encourage short, noncommercial descriptions that focus on technical capabilities, specifications, and possible applications.*

Preliminary Field Trials with the Newly Developed MVM1 Magnetic Viscosity Meter

by Dan Lynch, Lynch Rental LLC, Providence, Rhode Island (dan@lynch-mail.net)

Introduction

Recent tests were performed with a prototype down-hole probe designed to work with the new MVM1 magnetic viscosity meter (Figure 1) manufactured by Pulsepower Developments, Oxford, United Kingdom. This time-domain electromagnetic instrument is calibrated to read "frequency dependence of magnetic susceptibility" (κ_{fd} or x_{fd}). The magnetic viscosity results obtained *in situ* with the MVM1 can be directly compared to commonly used laboratory instruments that measure the frequency dependence of magnetic susceptibility. The development of a field portable magnetic viscosity meter that can directly read in frequency dependence of susceptibility units is significant because this type of measurement us usually confined to a laboratory setting.

Figure 1. (left) Surface (NPE-SE) and (right) borehole (NPE-BH) versions of the new electrode.

The frequency dependence of magnetic susceptibility is defined as ($\kappa_{fd} = \kappa_{lf} - \kappa_{hf}$) where κ_{lf} is low frequency and κ_{hf} is high frequency magnetic susceptibility. Volume frequency-dependent susceptibility (κ_{fd}) is used here so that the MVM1 down-hole results are directly comparable to the Bartington MS2-H down-hole logger system.

Calibrating the MVM1

Measured in the time domain, the amplitude of the magnetic viscosity response decays logarithmically versus time with an ideal slope of t^{-1}. The MVM1 has fourteen sample windows in the range of 10 to 100 µs. In the laboratory, one sample delay is selected to read directly as κ_{fd} so

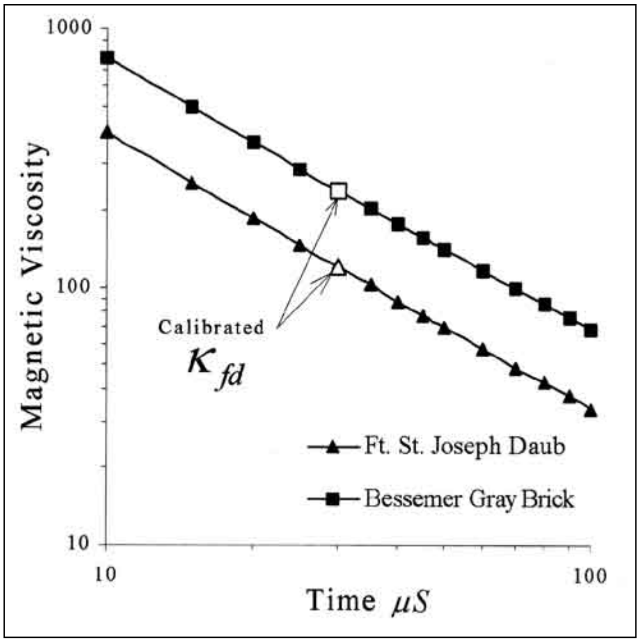

Figure 2. Log-log plot of the viscosity decay of two burnt clay samples. The first is a modern brick (Bessemer Grey from the Old Carolina Brick Co.), while the second sample is an archaeological sample of French colonial daub (late-17th to mid-18th century) from Fort St. Joseph, Michigan. The decay curves are calibrated in the time domain to read κ_{fd} at 30 μs.

Table 1. Bartington and Pulsepower Developments laboratory sensor susceptibility and magnetic viscosity data for the Bessemer Grey and Ft. St. Joseph burnt clay samples plotted in Figure 2.

	Bartington MS2-B				Pulsepower MVM1-B	
Sample	κ_{lf} 10^{-5} SI	$\kappa_{bf}10^{-5}$ SI	κ_{fd} %	κ_{fd}	κ_{fd} @ 30 μs	t^{-e} slope
Bessemer Grey	1933.2	1687.3	12.72	245.9	244	e = -1.17
Ft. St. Joseph Daub	1437.1	1319.0	8.22	118.1	118	e = -1.2

a calibrated plot of the magnetic viscosity decay curve can be mapped (Figure 2; Table 1). Because the logarithmic decay plot is directly calibrated to κ_{fd}, archaeological samples from diverse context can be compared in absolute terms to each other (Table 1). During the field trials, the 30 μs time-delay was calibrated to read κ_{fd}.

Results of the Down-hole Tests

The magnetic viscosity results presented here were performed during the 2008 National Park Service (NPS) “Current Archeological Prospection Advances for Non-Destructive Investigations in the 21st Century” in North Dakota, USA. The NPS workshop was hosted at the Biesterfeldt Site. Bieserfeldt is a contact-period Native American village site. Approximately half of this site has been plowed during some time in the past.

Pit-house “E” is one structure that was plowed and there are no surface expressions to indicate its exact location. Prior to this study, House E was delineated with a high degree of accuracy using the Bartington MS2-H down-hole system (Dalan and others, 2007).

Borehole #1 is located within the House E structure and a cultural layer at 25 to 30 cm below surface (cmbs) was noted during coring. Using the Bartington MS2-B sensor and the Pulsepower Developments MVM1 laboratory sensor, magnetic viscosity test were performed on collected soil samples (Figure 3A). The cultural layer between 25 to 30 cmbs corresponds to an increase in both magnetic susceptibility and magnetic viscosity at this location. These data are in good agreement with the Borehole #1 down-hole logs (Figures 3B, 3C). A possible buried paleosol is present between 50 to 60 cmbs on all of the logs. Borehole #2 is located about 7 meters outside of House E and is presented here for comparison (Figure 4). No obvious cultural soils were observed in the soil core at borehole #2.

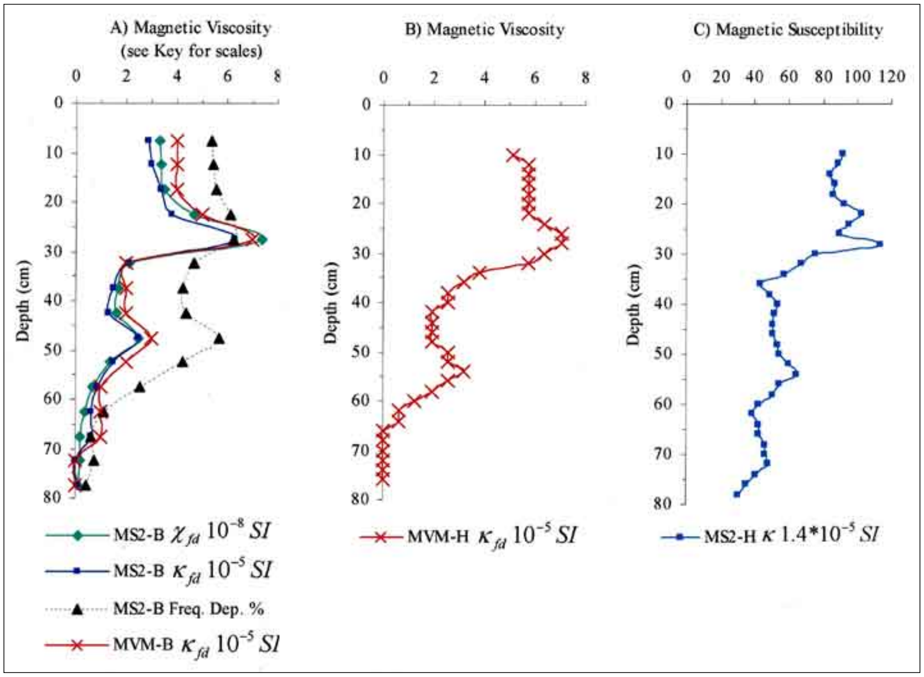

Figure 3. Borehole #1, inside House E. (A) Soil samples collected at 5-cm intervals. Diamonds, squares, and triangles measured on a Bartington MS2-B dual-frequency sensor. Cross "X" measured on a Pulsepower Developments lab sensor. Note the different scales in the key. (B) MVM1 prototype down-hole probe data collected at 2-cm intervals. (C) MS2-H down-hole magnetic susceptibility data collected at 2-cm intervals.

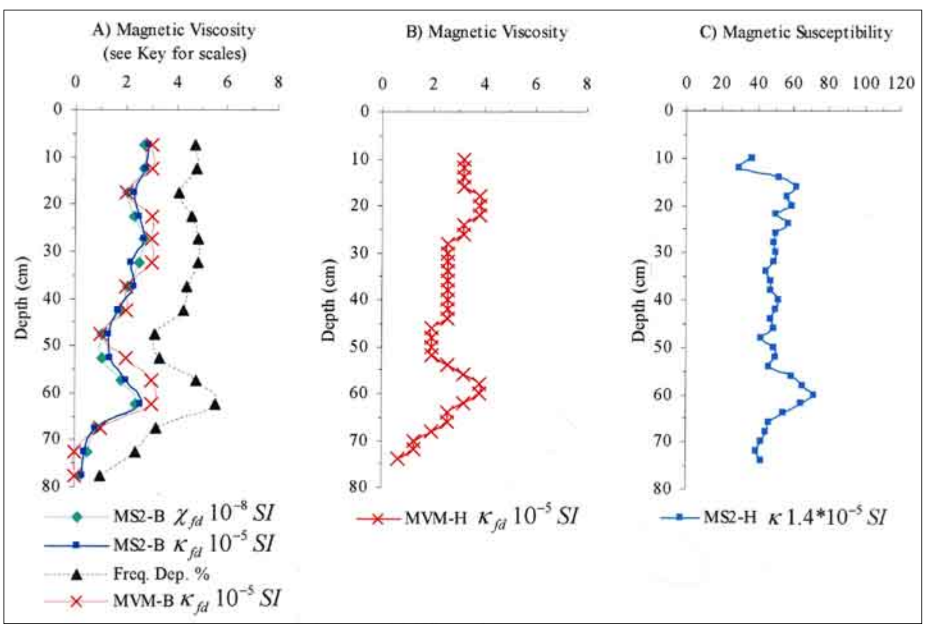

Figure 4. Borehole #2, outside House E. (A) Soil samples collected at 5-cm intervals. Diamonds, squares, and triangles measured on a Bartington MS2-B dual frequency sensor. Cross "X" measured on a Pulsepower Developments lab sensor. Note the different scales in the key. (B) MVM1 prototype down-hole probe data collected at 2-cm intervals. (C) MS2-H down-hole magnetic susceptibility data collected at 2-cm intervals.

Conclusion

A newly developed magnetic viscosity meter was tested for its ability to detect cultural deposits at the Biesterfeldt site. The results of the down-hole tests are encouraging. Previously, measurements of κ_{fd} were confined to a laboratory setting. These results suggest that it is now possible to record magnetic viscosity in the field as κ_{fd} with the new MVM1 time-domain instrument.

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Success with Geophysics: Archaeology

***FastTIMES** welcomes short articles on applications of geophysics to the near surface in many disciplines, including engineering and environmental problems, geology, soil science, hydrology, and archaeology. In the four articles that follow, we glimpse how noninvasive geophysical methods have improved archaeological investigations.*

Ground-penetrating Radar Processing and Interpretation Techniques for Archaeology

by Lawrence B. Conyers, Department of Anthropology, University of Denver, Denver, Colorado 80208 (lconyers@du.edu)

Introduction

Ground-penetrating radar (GPR) has recently gained a wide acceptance in the archaeological community as a method to quickly and accurately locate buried archaeological features, artifacts, and important cultural and geological strata in the near-surface. The GPR method has now become one of the primary tools for geophysical feature identification primarily because of its three-dimensional abilities, and the ability to work around modern cultural features such as buildings, fences, and metal objects without a great deal of interference. While radar energy depth penetration limits (to at most about five meters in most ground conditions) can limit GPR's ability to map very deep features, most archaeological features around the world are located within that depth range. Historically the archaeological community has used GPR to identify buried remains for protection and future preservation, or to identify them for selective excavation. Recently, GPR has gone far beyond this historical application and has been used as a tool for collecting "primary data" from archaeological sites, which can be used to test ideas about ancient cultures in much the way standard archaeological data can (Kvamme, 2003; Conyers and Osburn, 2006).

Today's GPR systems are quite compact, easy to use, and can easily be transported around the world in a few check-through cases. Rarely have I been detained by customs personnel, as long as documentation is obtained in advance from a local in-country sponsor or institution, and the ownership of the equipment and its value is noted in the paperwork. All GPR systems used today are digital and compact. Antennas are usually attached to a survey wheel or GPS system for distance measurement along transects (Figure 1). Reflection data can be quickly transferred to small flash drives and transferred to laptop computers for rapid processing and map construction using a variety of software written specially for archaeological applications. Prototype GPR systems have been developed that transmit reflection data wirelessly to a nearby computer, and maps of the ground are constructed in "real time" as reflection profiles are collected (Grasmueck and Viggiano, 2007). Multiple antenna arrays are also being explored to produce "real 3-D" data, imitating seismic acquisition and processing methods.

Figure 1. Collecting GPR data using a GSSI SIR-3000 system and 400 MHz antennas attached to a survey wheel.

Collecting GPR Data in Archaeological Contexts

For archaeological applications, radar antennas are usually moved along the ground in linear transects and two-dimensional profiles of a large number of reflections are created, producing a profile of subsurface stratigraphy and buried features along each line (Figure 2). Antenna frequencies close to 400 MHz are the most widely used for archaeology. They transmit energy to about 3- to 4-meters depth in many ground conditions and have a feature resolution of about 30 to 40 cm, which is usually ideal for archaeological identification. With the 400 MHz antennas transect spacing is usually 50 cm or less, which creates a footprint of energy transmission in the ground giving complete coverage of buried materials. When data are acquired in a series of transects within a grid using this transect spacing, radar reflection wave amplitude maps can produce very accurate three-dimensional images of buried features and associated stratigraphy.

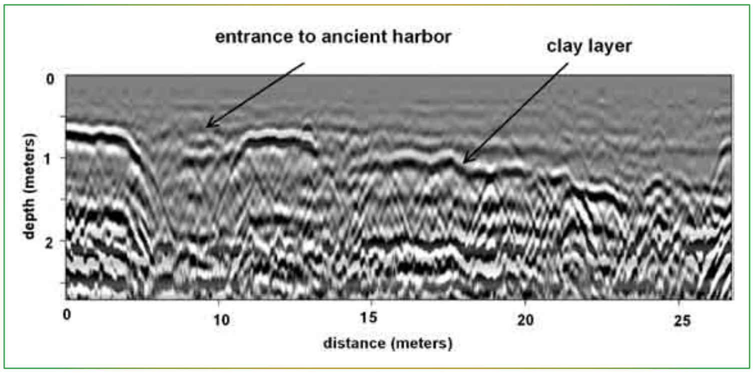

Figure 2. Reflection profile across an ancient harbor in Israel. Homogeneous near-shore sand overlying the clay produces very few reflections. A gravel layer below the clay layer produces many hyperbolic reflections, generated from each large gravel clast. In this profile the entrance to an ancient harbor, dredged through the clay and gravel, can be seen as a deep incision through those layers.

The success of GPR surveys is to a great extent dependent on soil and sediment mineralogy, clay content, ground moisture, depth of burial of features, surface topography, and vegetation. It is common to be confronted with very different ground conditions than one would expect when called in as a consultant on other's projects far from home. I have found that many archaeologists are not aware of the geological or ground conditions suitable for geophysics at their sites. In cases of this sort my students and I are often told in advance that the ground surface is "clear" and the soil is "sandy," only to find that the site is covered in sagebrush or trees, and the soil is actually water-saturated clayey silt. This never ceases to amaze me, and I can only conclude that most archaeologists spend too much time gazing into their small 1 x 1 meter excavations and are not aware of the overall landscape or the nature of soils and sediments in the area as a whole. When this occurs, all one can do is modify collection and processing procedures from what would be optimum, and hope that one's experience can still provide usable results. Interestingly, we have found that wet ground conditions and even wet clay need not preclude the use of GPR, as was thought in the early days of the method's development. Our experience shows that excellent GPR data can be obtained even in totally saturated clay soil (Conyers, 2004b; Conyers and Connell, 2007). The limiting factor in cases like this is not clay or water *per se* but the mineralogy of the clay and the amount of dissolved salts in the water that affects energy attenuation.

One of the advantages of GPR surveys over other geophysical methods is that the subsurface stratigraphy, archaeological features, and soil layers at a site can be mapped in real depth. This is always very important in archaeological contexts because accurate depth is a crucial element in planning future excavations based on the results of a GPR survey. Velocity analysis is therefore extremely important, using a number of field collection and processing procedures (Conyers, 2004a).

Analysis of reflection profiles can be a very effective interpretation method, but is usually only possible after a good deal of experience with the GPR method. GPR profiles often do not "look like" what one would expect from stratigraphic layers or archaeological features, if one were comparing them to those visible, for instance, in the wall of a back-hoe trench. This is because as radar energy propagates in the ground it spreads out in a cone, and the resulting reflections are returned to the surface antenna from the front, back and sides, creating a somewhat complex profile with distorted planar reflections and an abundance of hyperbolic reflections. In addition, distorted planar reflections are caused by velocity variations both with depth and laterally that are usually un-knowable. The abundance of hyperbolas in many profiles is created from reflections within the conical transmission pattern from “point sources” in the ground such as rocks (Figure 2). These, and other factors that create a less than clear picture of the ground, must be taken into account when interpreting reflection profiles.

Profiles also contain high and low amplitude reflections created at the interfaces of materials that differ greatly in chemical and physical properties (Conyers, 2004a). If information is available about the lithology of buried sediments and soils, layers of interest can be identified and mapped throughout a grid (Figure 3). This can be of great value, as these types of data can place archaeological materials within a geologic context using an analysis of the depositional environments of individual layers, and therefore be used to show environmental changes over time. The placement of archaeological features in the ancient landscape using GPR stratigraphic analysis is one of the method’s great values (Kvamme, 2003).

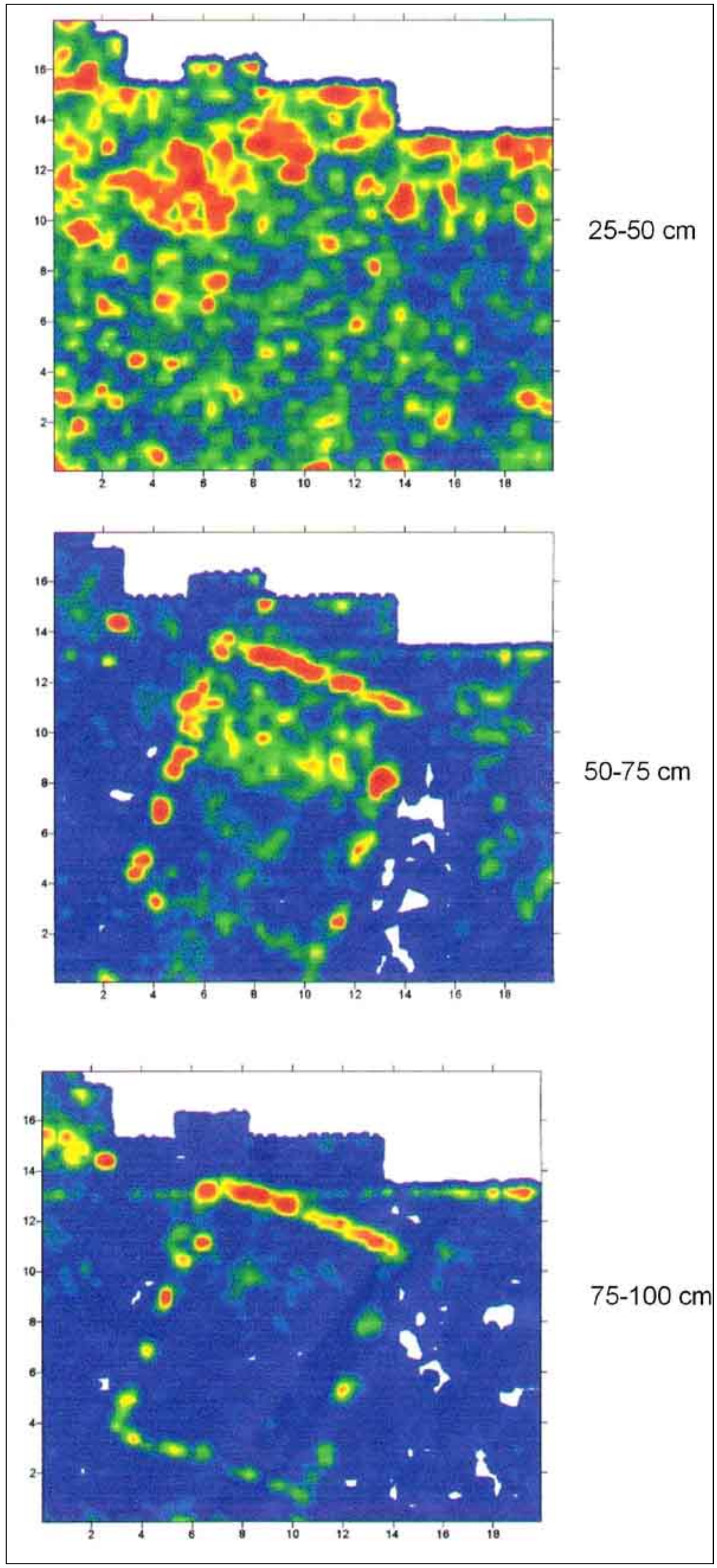

Figure 3. Example of amplitude slice-maps showing columns and walls of a buried Roman temple at Petra, Jordan in the lower slices from 50 to 100 cm depth. These images are about as good as they get with GPR in archaeology, as this cut-stone structure is covered by a layer of wind blown quartz sand and surface rubble. The buried structure is essentially intact.

Analysis and Interpretation of GPR Reflection Data

Standard two-dimensional reflection profiles can be used for some basic data interpretation, and given enough time, tedious profile-by-profile interpretation can be quite useful. However, it is often the primary goal of most GPR surveys for archaeology to identify the size, shape, depth, and location of both buried cultural remains and related stratigraphy (and do it quickly). The standard way to accomplish this goal just a decade ago was to visually identify and correlate important reflections within two-dimensional reflection profiles and then correlate them from profile to profile throughout a grid, creating a “manually produced” map of the subsurface. This can be not only time consuming but often inaccurate as it can contain human errors. Recently most archaeological GPR work has employed amplitude slice-map analysis, which creates maps of reflected wave amplitude differences within a grid in horizontal slices in the ground (Conyers, 2004a). The result is a series of image maps that illustrate the three-dimensional location of reflections derived from a computer analysis of the two-dimensional profiles (Figure 3). This method of data processing is very fast, and is usually the first type of processing that my students and I do after transferring reflection data to a computer. Using this method every reflection amplitude in every profile is compared and interpolated with every other amplitude along a defined distance in the same profile and in adjoining profiles within a grid to produce images of the spatial extent of high and low reflective buried features. This is done in “time slices” (within certain vertical windows, defined in nanoseconds of two-way radar travel time), which are converted to “depth slices” if velocity analysis has been performed (Figure 3). The result can yield very important images of buried objects or natural features that produce reflections of varying intensity. Cultural objects can usually be discriminated from natural features based on an evaluation of their shape, as can be readily identified in the buried Roman temple shown in Figure 3.

In most cases the buried archaeological features of interest are less readily identified than the temple shown in Figure 3, and individual reflections profiles must also be interpreted in order to identify the origin of reflections of interest that might be visible in amplitude maps. In this process, features visible in horizontal depth slices are evaluated by vertical profiles, and the three-dimensional aspect of reflective objects the ground can be discerned.

Amplitude slices need not be constructed horizontally or even in equal time intervals. They can vary in thickness and orientation, depending on the questions being asked. Surface topography and the subsurface orientation of features and stratigraphy of a site may sometimes necessitate the construction of slices that are neither uniform in thickness nor horizontal, or are modified to take into account antenna tilt and the resulting variation in the cone of transmission (Goodman and others, 2006).

Often it is difficult to predict in advance what archaeological features should look like as a series of reflections in GPR profiles. As an aid to interpretation, the complex nature of radar travel paths in the ground can be simulated in two dimensions using synthetic models (Goodman, 1994; Conyers and Goodman, 1997). In this method, predicted features are modeled on the computer and assigned values of electrical conductivity and relative dielectric permittivity. The computer can then simulate radar wave travel paths and wavelengths of energy based on selected antenna frequencies. The conical transmission pattern of energy spreading is also simulated, and the resulting reflections from buried objects or stratigraphic interfaces are modeled in a synthetic reflection profile (Figure 4).

Synthetic reflection profiles can then be compared to actual profiles from the field as an interpretation aid. When the synthetic profile shown in Figure 4 was compared to profiles collected in an olive grove in Tunisia (Figure 5), the exact reflection features predicted in the model were discovered. In this method,

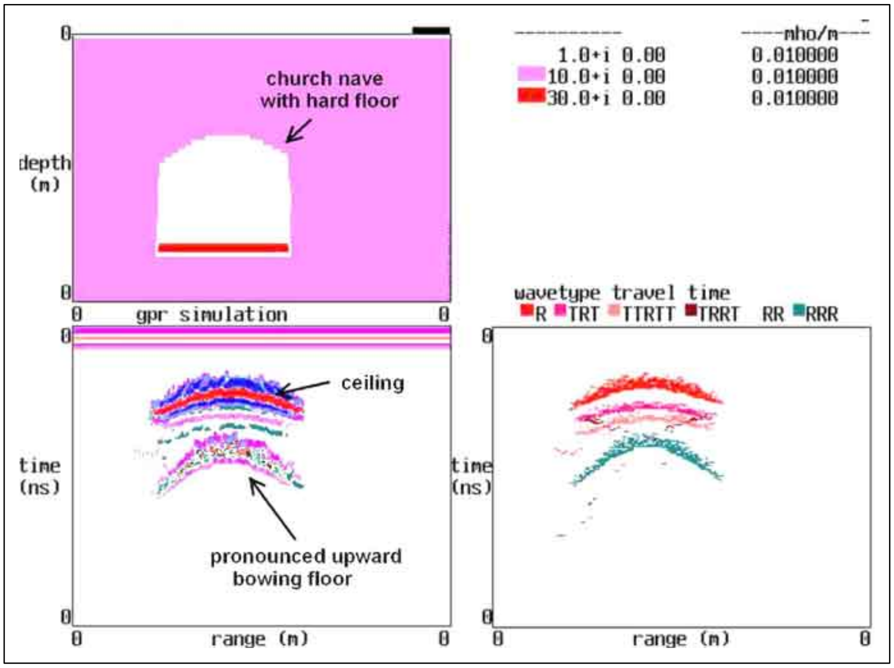

Figure 4. Synthetic reflection profile generation of an underground church in Tunisia. Only the ceiling, floor and walls of the church were simulated, producing reflections that accurately depicted the upward bowing ceiling, and a pronounced upward bowing floor. The floor reflection distortion is created by a velocity "pull up" as energy is transmitted at the speed of light within the church cavity, but at much slower rates elsewhere in the ground. The walls are invisible, as transmitted energy is passed parallel to them and if reflections occurred, the resulting waves were transmitted away from the surface antennas and not recorded.

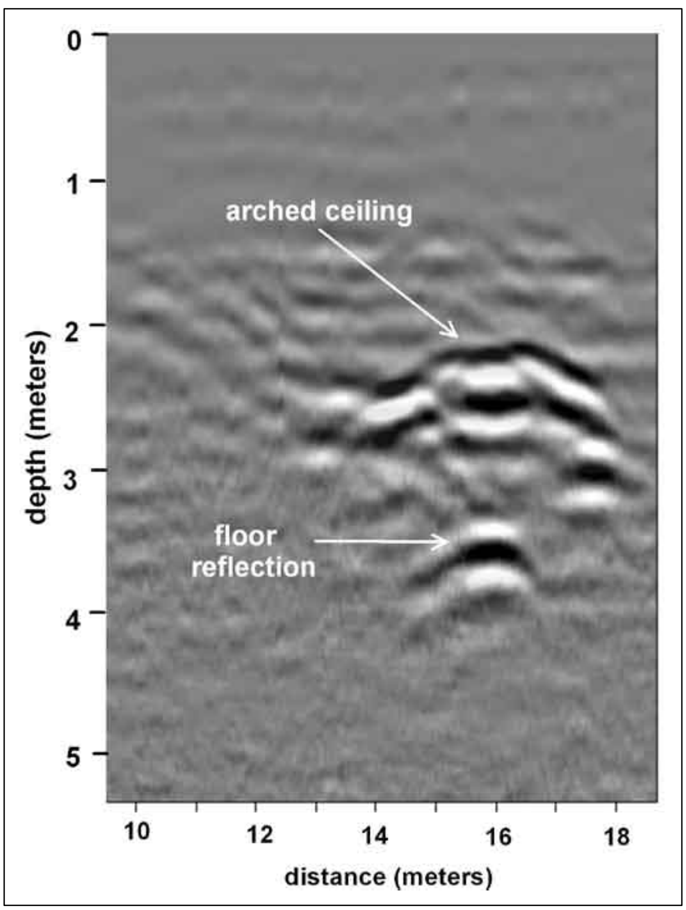

Figure 5. 270 MHz reflection profile across an underground church in Tunisia, which shows much the same reflection features as modeled in advance (Figure 4).

the comparison of the model to the actual GPR reflection profiles provided a great deal of confidence in the interpretation and a guide to excavations.

Other images that can be of value in visualizing buried archaeological features are isosurfaces (Conyers, 2004a). In this method, a three-dimensional package of reflections within a grid is analyzed in batch. All reflections of certain amplitudes are then displayed as "objects," while amplitudes below a certain threshold are made transparent. The resulting reflection features, which can often mimic actual archaeological feature in the ground that produced the reflections, are then displayed with artificial sunlight, and at varying angles of visibility (Figure 6). In this way a "virtual reality" image of features can be produced that can help greatly in interpretation, especially for archaeologists with no geophysical training.

A number of other interesting GPR processing and interpretation methods have been developed that show great utility in future archaeological applications (Conyers, 2006). Frequency filtering of reflection records allows for the display of only certain bands of energy, allowing either larger or smaller objects in the ground to be enhanced or filtered out (Grealy, 2006). In this way, certain objects or

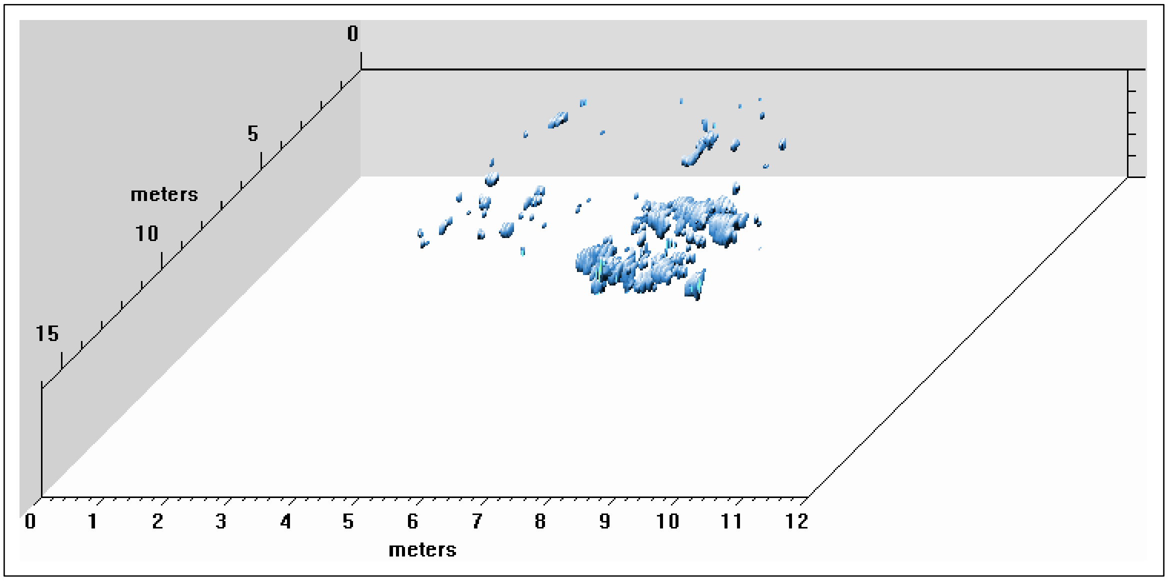

Figure 6. Isosurface map of the highest amplitude reflections from a pit-house floor preserved within sand dunes along the Oregon coast. Random stones, probably related to human activity in the dunes can be seen as small reflections scattered above and around the sunken house floor.

perhaps buried architecture at specific depths can be visualized and others removed or ignored. Reflections within the “near-field” of the antenna can also be used to produce maps of the ground using frequency filtering and background-removal and careful range-gaining processing (Ernenwein, 2006). In this way, reflection data recorded very near the ground surface, which just a few years ago was often ignored as unusable, can produce important images of shallow features. Experienced archaeological geophysicists are also beginning to appreciate the ability of GPR to discern buried features that are almost invisible to the human eye when excavated and exposed to view. Often the chemical and physical contrasts of these features are so slight that only low amplitude radar waves are reflected back to the surface. But careful analysis of these amplitudes can still provide accurate maps of very subtle features, as the digital information is available, even though it may not be visible to the human eye (Weaver, 2006).

An important re-direction in the use of geophysics for archaeology has been GPRs ability to test cultural models about the human past. Most archaeological geophysics is still focused on its original application of finding buried objects or features that can later be excavated using traditional methods. As most of us working in geophysical archaeology can today routinely produce accurate three-dimensional images of the ground, a few of us believe that it is now time to use this ability to test hypotheses about human activity across large areas, social organization and many other anthropological questions. For instance, if models of historic human activity can be related to the placement, orientation, shape and clustering of buried architecture, then GPR mapping is capable of accurately testing these hypotheses or developing new ideas about the past (Conyers and Osburn, 2006). GPR can potentially tell a great deal about archaeological sites without ever having to excavate, which will be of great benefit in the future as traditional archaeological digging becomes more expensive and often curtailed due to preservation issues.

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Ground-penetrating Radar Tomography of a Mayan Pyramid Ruin

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Abstract

In 2008, a GPR survey was conducted on a Maya pyramid ruin in Belize, Central America. The pyramid stands some 15 m high with an approximately 28 m by 28 m base. The purpose of these surveys was to determine whether GPR tomographic techniques could be used to create velocity images of the limestone pyramid. Traveltime picks were taken from the transmission wave after applying a FK filter to the raw gathers.

Two different approaches were used to help find the velocity structure. A straight-ray approach successfully solved for a velocity model with traveltime residuals (measured minus calculated) measuring approximately 3 ns. However, multiple "nonphysical" values were derived. The curved ray technique solved for a velocity model with traveltime residuals around 4.5 ns. This method produced no nonphysical values, but tight velocity constraints of 0.07 m/ns to 0.11 m/ns had to be implemented.

Figure 1. Rob Stewart using the pulseEKKO Pro system on the Maya pyramid at Maax Na.

Introduction

Ground-penetrating radar (GPR) has often been used in archaeology to help locate objects and structures buried in the earth. GPR is extremely sensitive to the electromagnetic properties of the subsurface and therefore can detect subsurface anomalies that may be of interest to archaeologists. However, because GPR has a limited penetration distance, seismic techniques are used instead when performing tomography on large structures. While seismic tomography has been proven effective (Allen and Stewart, 2007; Cardarelli and de Nardis, 2001; Polymenakos and Papamarinopoulos, 2007), the equipment used is typically heavy and awkward. This makes it difficult to work in remote areas where archaeological excavations commonly take place. GPR is a possible solution to this problem as the equipment is lighter and more mobile.

In 2008, a GPR survey was acquired around a Maya pyramid in Belize at the Maax Na archaeological site (Figure 1). The pyramid is approximately 28 m by 28 m with a height of 15 m. It consists of carbonate rock and mortar covered with a layer of loose soil. The GPR survey was acquired using Sensors and Software's pulse EKKO Pro system with 100 Mhz antennas. Eight different transmitter locations were used along a thirty-meter line with 151 different receiver locations placed at 20-cm intervals (Figure 2). Both straight- and curved-ray tomography techniques were used to solve for the velocity structure.

Data Analysis

The 100 MHz antennae on the pulseEKKO Pro system produced on average a relatively broadband signal up to 100 MHz. The peak frequency appears to be approximately 50 MHz for all the shots. Fig-

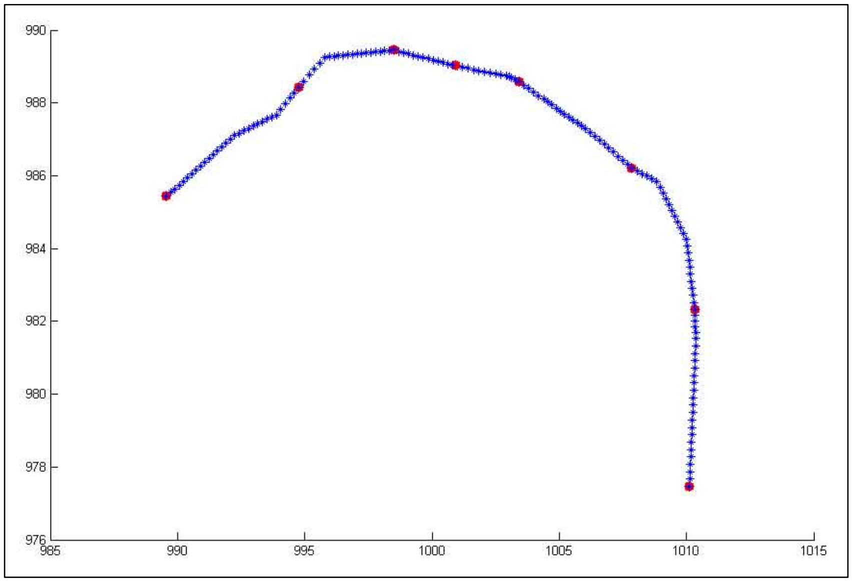

Figure 2. Source and receiver layout. Sources are shown in red and receivers are blue.

ure 3 shows the frequency/amplitude graph as well as the time/amplitude graph for the shot from position 2. The remaining shots display similar results.

Unlike seismic surveys, the direct transmission wave is not the first arrival on the shot gather. In a typical GPR survey the first arrival is the airwave, which must be ignored in order to get the traveltimes of the transmission wave. Since the GPR shot gather has a significant amount of noise it is difficult to distinguish the transmission wave from noise or the air wave (Figure 4). Despite the worries of depth of penetration, the transmission wave appears to penetrate about ten meters on either side of the shot.

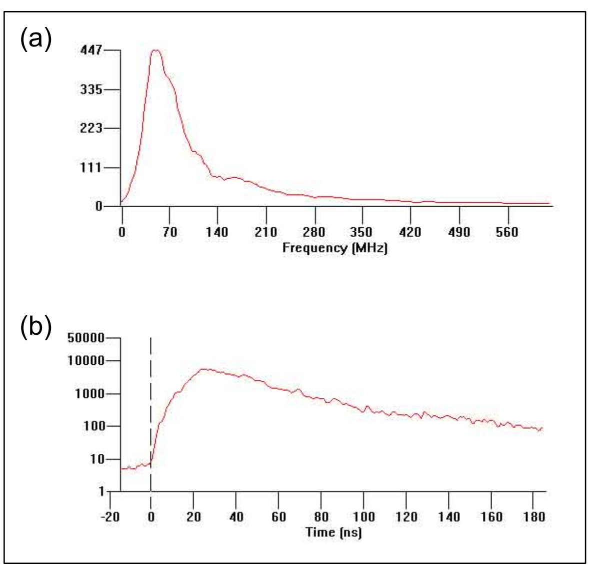

Figure 3. The (a) amplitude-frequency graph and (b) amplitude-time graph for shot 2.

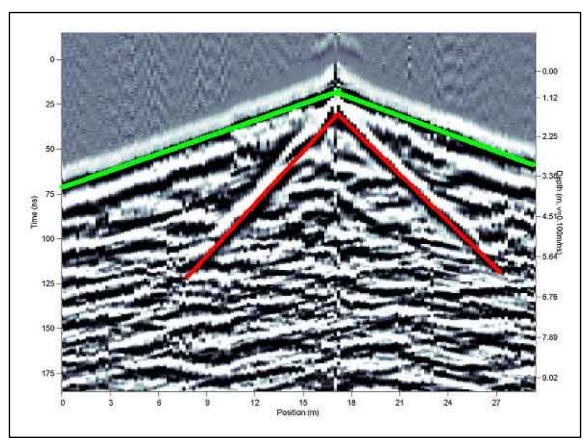

Figure 4. A sample shot from the GPR survey. The air-wave marked in green and the transmission wave marked in red.

An FK filter was used on the shots to better see the transmission wave (Figure 5). By applying the FK filter, a clear view of the transmission wave without the airwave and much of the noise is seen in Figure 6. This allows for a greater number of traveltimes to be picked.

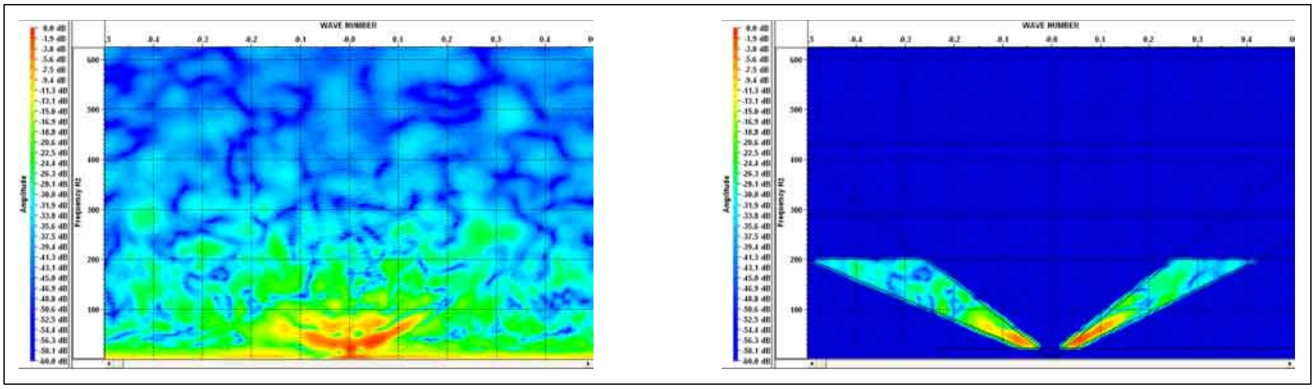

Figure 5. The initial FK spectrum (left) of the final shot gather and the final FK spectrum (right) after the filter has been applied.

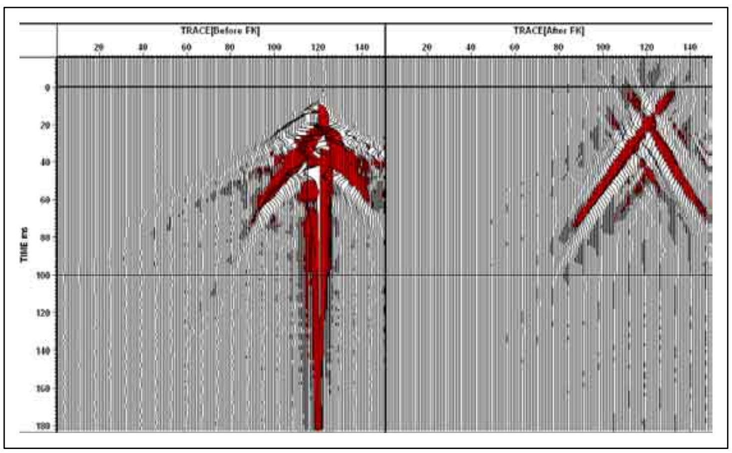

Figure 6. The shot gather before (left) and after (right) applying an FK filter.

When picking the traveltimes, multiple values receivers had to be ignored near the shot location due to the clipping between the airwave and the transmission wave. Once all reliable picks had been made, a total of 735 traveltimes remained.

In solving for the velocity structure, a grid size of 0.5 m by 0.5 m was used for both the straight and curved ray techniques. This grid size was chosen due to the close spacing of the receiver locations. Since a large percentage of area that this GPR survey is covering is the loose soil layer, the velocity can change quickly and a smaller grid size will better image this. The resulting small grid size does result in a lower fold, but the majority of pixels retain an acceptable level of fold.

Straight-Ray Inversion

To solve the straight-ray inversion, the conjugate gradient method (Yilmaz, 2001) was used with a total 30 iterations. The derived velocity structure resulted in several negative values. Since these negative values are nonphysical, they were set to zero. Along with the negative values, there were a few velocity values that appeared too high to be physical. These high velocity values were set to 0.2 m/ns.

The value of 0.2 m/ns was decided to be the maximum based on previous years' GPR surveys performed on the plaza area of Maax Na by Aitken and Stewart (2004). In these surveys, velocities were found to range between 0.072 to 0.106 m/ns in wet conditions and 0.122 to 0.140 m/ns in dry conditions. Since the plaza was made of similar carbonate as the pyramid, these velocities were used as a guideline in determining the maximum velocity. A maximum velocity of 0.2 m/ns was decided upon due to the fact that the fill in the pyramid may be less dense then that of the plaza and therefore may have slightly faster velocity. The final velocity structure can be seen in Figure 7.

A new set of traveltimes was derived based on the modeled velocity structure found by the straight ray tracing. The negative values and high velocity values were included in the model. The derived traveltimes were then compared to the original traveltime picks. The results can be seen in Figure 8. The average of the absolute value of the differences was found to be 2.942 ns with a standard deviation of 3.242 ns.

Curved-Ray Inversion

To solve for the velocity structure using curved-ray traveltime inversion, we used the 2Dray_tomo program created by Zhou and others (1992b). This program uses the minimum traveltime method of Moser (1991) and Zhou and others (1992a). This method uses a number of nodes on the grids that are connected to create the shortest path between source and receiver as well as a fast and efficient damping L2-norm inversion algorithm (Zhou and others, 1992a). For this survey, the maximum amount of 25 nodes per grid were used along with a damping factor of 1×10^{-6}.

Multiple velocity constraints were tried before the range of 0.07 m/ns to 0.11 m/ns was determined to work the best with a starting constant velocity model of 0.1 m/ns. This velocity constraint resulted in the lowest average differences in traveltimes as well as the lowest standard deviations. Once the velocities were decided upon, a total of 150 iterations was undertaken to find the minimum average differences. Upon comparison (Figure 9), iteration 137 proved to give the

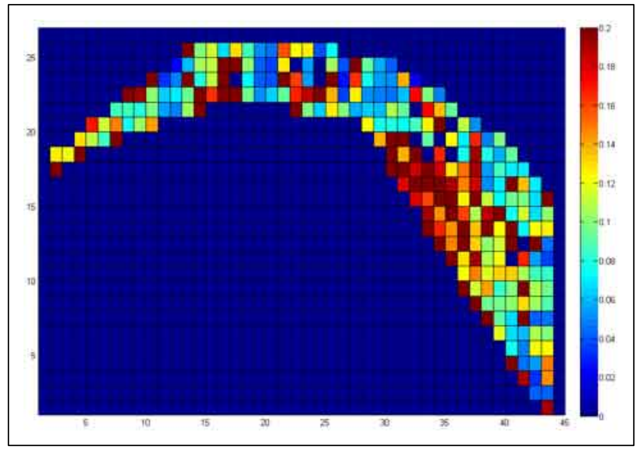

Figure 7. The final velocity (m/ns) structure derived from straight-ray traveltime inversion. All negative values set to 0 m/ns. All velocities greater than 0.2 m/ns are set to 0.2 m/ns.

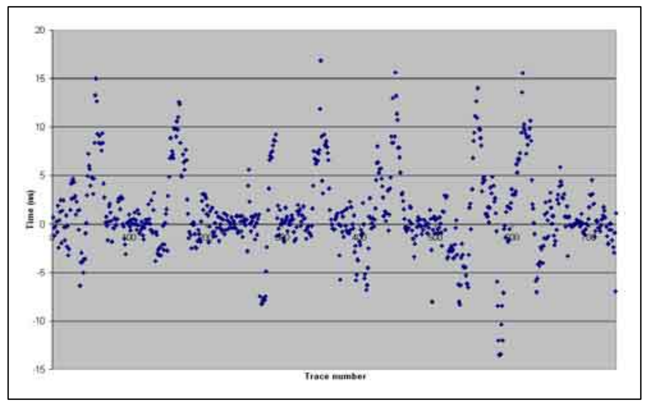

Figure 8. The difference between the measured and calculated traveltimes.

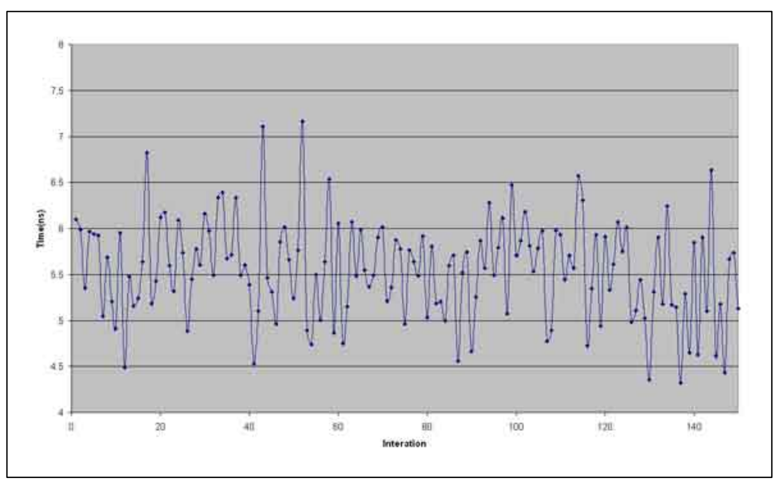

Figure 9. Average of the differences between measured and calculated traveltime for each iteration of curved-ray traveltime inversion.

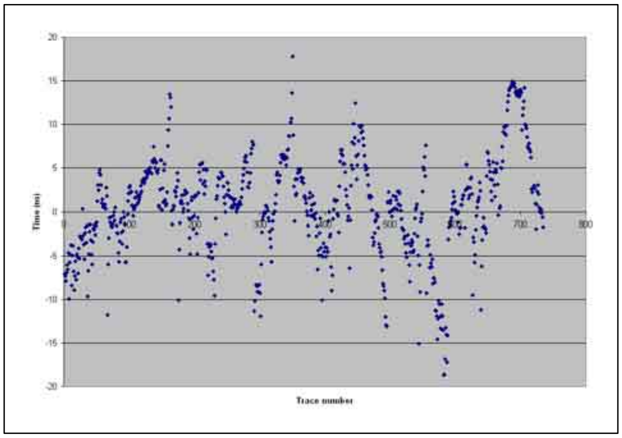

Figure 10. Differences between measured and calculated traveltimes for the 137th iteration velocity model.

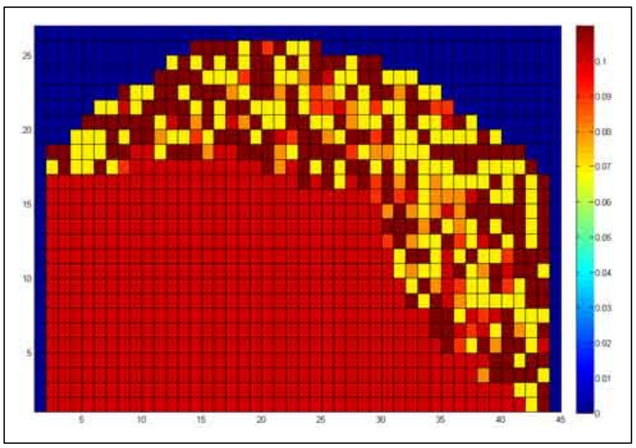

Figure 11. The final velocity model (m/ns) derived from the curved-ray traveltime inversion. Parts of the initial model of 0.1 m/ns remain in areas of no ray coverage.

best velocity model, with an average of the absolute value of the differences with 4.324 ns and standard deviation of 5.695 (Figures 10 and 11).

While the average difference and standard deviation of the curved-ray inversion is higher than that of the straight ray, there are no nonphysical values in the curved ray trace resulting in a more reliable velocity structure. To get a better velocity model, a larger number of sources or receivers should be included to allow for high fold and a larger possible velocity range.

Conclusions

In analyzing the capability of GPR to be used in large structure tomography, it was seen that the wave can penetrate adequate distances. In this survey, a 100 MHz GPR antenna was used and the wave penetrated a distance of about 10 m on either side of the shot. A lower frequency antenna should be able to expand the penetration depth.

The straight-ray traveltime inversion produced a velocity model with the majority of velocities in an acceptable range determined by previous GPR surveys in the plaza area. However, there were several negative as well as excessively large velocity values given. These nonphysical values tended to appear in areas of low fold. With increased source points, the values should further converge to the actual velocity model.

The curved-ray model was able to produce an accurate velocity model after finding appropriate velocity constraints of 0.07 m/ns to 0.11 m/ns. Using these constraints, the average difference between the measured and calculated traveltimes was reduced to 4.324 ns. This was a little higher than that of the straight-ray inversion, but the curved-ray approach had no nonphysical values and its velocity model is more likely to be accurate. To increase the accuracy, a greater number of source and receiver points must be included. This should allow the velocity constraints to be widened.

Finally, we see that GPR is a possible alternative to seismic techniques in solving tomographic problems on larger structures.

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Finding Lost Settlements with Multi-channel 3D GPR: Examples from North Carolina and Florida

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Introduction

For some time, archaeology has employed many geophysical methods, including single-channel ground-penetrating radar (GPR). But more than any other new geophysical surface technology, the GPR array systems that have been commercially available for the last five years now have the potential to become an important tool for effective archaeological research. We will discuss two case studies where Radar Tomography (RT) has provided archaeologists with clear isolated targets, which increases the potential of a successful excavation. After describing the geophysical approach, we will explore the findings of the “First Colony” RT survey followed by the results of the “Looking for Angola” RT survey.

Geophysical Approach

The geophysical approach is based on efficiently collecting GPR data with a multi-channel system and combining it with precise positioning (cm accuracy) using a robotic total station or RTK GPS and advanced signal processing, allowing the creation of high-resolution 3D radar images of the subsurface on a large-scale (order of 10,000 m^2). These images are used to create engineering maps of the located features, including 3D underground utility lines (Birken and others, 2002a, b, 2007) and archaeological features. Figure 1 summarizes this method, which we refer to as Radar Tomography (RT).

Figure 1. Radar Tomography method. Collecting GPR data with a multi-channel system (Top row images: commercially available GPR array systems), combining it with precise positioning using a robotic total station (bottom left), advanced signal processing allowing the creation of high-resolution 3D radar images of the subsurface on a large-scale (center: one radar depth slice of a large intersection), and finally converting the 3D-located utilities into engineering-type CAD drawings (bottom right).

Both surveys were conducted with a 16-channel, 200 MHz GPR array system (Figure 1, top left). The array covers an almost 2-m wide swath collecting GPR data every 14 cm across lines and every 10 cm in-line, providing a data density that allows for full resolution 3D imaging (Grasmueck and others, 2005) at driving speeds of up to 5 km/h. Such a system can cover up to 10,000 m^2 in one day, depending on the site conditions. The array movements were tracked with cm accuracy by a robotic total station (Figure 1, bottom left).

Processing the raw radar data into images involves several steps. Data are filtered with pre-processing algorithms that align traces in each channel and balance channels with filters that remove static shifts and match the mean (or median) response across channels (based on a reasonable assumptions about the response in certain areas of the survey). Radar data is then merged with geometry data, gridded, and migrated to produce 3D radar images of the subsurface (Oristaglio and others, 2001).

RT as described above was used to map archaeological features at both sites. In January 2008, a 2014 m^2 (21,679 ft^2) RT survey was conducted in four and a half hours at the Fort Raleigh National Historic Site (FORA) on Roanoke Island, Dare County, near the coast of North Carolina (Figures 2 and 3). In July 2007 a 6309 m^2 (67,915 ft^2) RT survey was conducted in a day and a half on the south side of the Manatee River, on the property of Reflections of Manatee, Inc., a historic preservation organization that protects the Manatee Mineral Spring (Figure 4). The property is in the city of Bradenton, on Florida's Gulf Coast (Figure 5).

Figure 2. Picture of the radar array collecting RT data in open woodland at FORA.

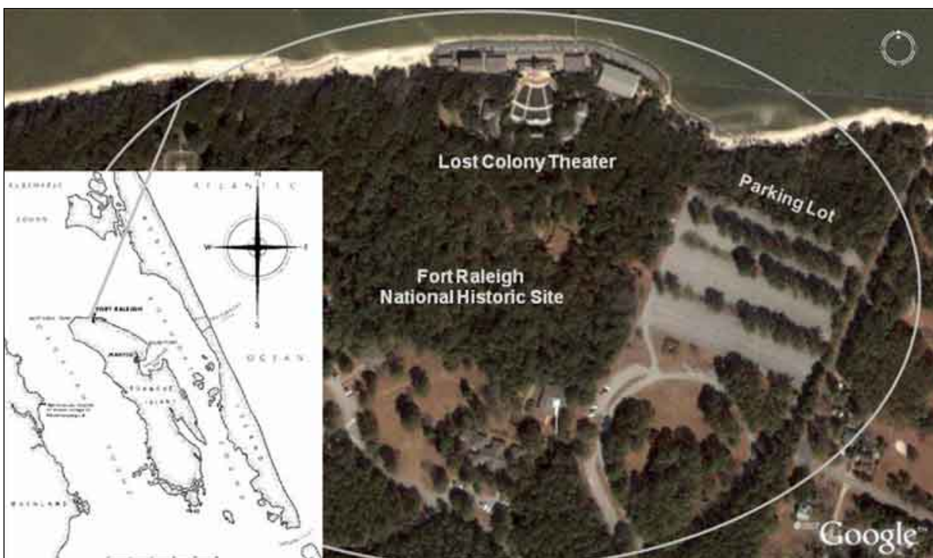

Figure 3. Aerial photograph showing parts of the Fort Raleigh National Historic Site (from Google Earth). Inset is a map of Roanoke Island off the coast of North Carolina (Harrington, 1962).

The First Colony

Historical Background

The first English colony in America was established on Roanoke Island in 1585 by Sir Walter Raleigh in the land he called "Virginia" in honor of Queen Elizabeth (Quinn, 1991). This military force was withdrawn after a year, and in 1587 a second, civilian colony arrived to establish families and farms. There was no sign of the colonist in 1590, and the mystery of their fate gave rise to the story of the Lost Colony. A small earthwork on Ronaoke Island has been traditionally attributed to the Elizabethans and was confirmed by National Park archaeological excavations in 1947-50 that reconstructed the fort. No evidence was found of the settlement then or in later searches in the 1950s and 60s (Harrington, 1962).

Figure 4. Picture of the radar array collecting RT data near the Manatee Mineral Spring.

Figure 5. Aerial photograph (from Google Earth) showing the RT survey area near the Manatee Mineral Spring in Bradenton, Florida.

A small structure near the fort was located in 1965 and further excavated in 1991-2, when it was identified as preserved remains of a scientific workshop that investigated the resources of North America in 1585-6 (Harrington, 1966; Noel Hume, 1994a, b). Resistivity survey and ground penetrating radar have been applied to several areas of the five acres surrounding the earthwork, but the results have been inconclusive. Except for these two structures, no remains of the people, houses, or forts of either the 1585 military colony or the 1587 "Lost Colony" have yet been found. Since 2006, the First Colony Foundation (FCF) has undertaken fieldwork in partnership with the National Park Service (NPS) in search of evidence for the Elizabethan colonies.

RT Results

The RT survey was designed to test the equipment by covering areas with known subsurface targets and areas without knowledge of the subsurface features on four different ground surface types to gauge the comparative results of RT, in relation to adjacent areas of excavation: parking lot, grass, asphalt drive, and open woodland (Figure 2). The RT survey results were displayed in two ways: (1) a “virtual excavation” of vertical videos descending from 1 inch to 100 inches below ground surface, and (2) a CAD drawing map showing major anomalies as interpretive features, typically utilities (Figure 6).

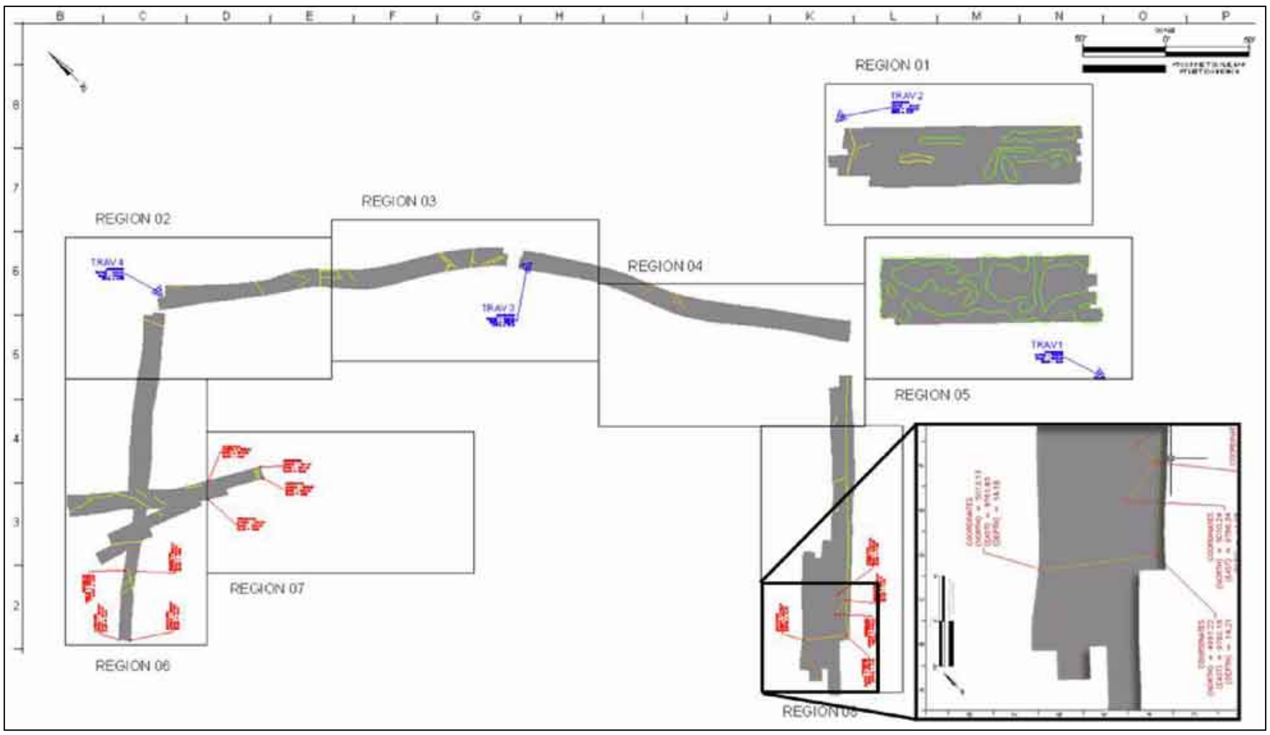

Figure 6. CAD drawing map showing surveyed areas in gray, parking lot (Figure 3) is surveyed in regions 1 and 5. Major anomalies are shown as interpreted features (typically utilities, but also archaeological ones). Inset on bottom right indicates locations of features excavated in unit 27 and 28 (Figure 7).

The first test area was the western 150 ft of the northern two segments (each 40-ft wide) of the theater parking lot. RT clearly showed the storm drain along the western edge of the area. It also showed a rectangular anomaly in the center of the lot, and even caterpillar tread marks from bulldozing operations. Below 20 inches, cloudy, billowing images indicate heavy clays.

A second test area was a 20- to 40-ft wide strip of grassland west of the parking lot and 180 ft south of the ticket booth. Here RT imaging picks up a water line running NW-SE and the thin line of an electrical or telephone cable. It also reveals the tendril-like images of tree roots and a N-S line of postholes and/or tree holes on the property line between the former state park and the Dough farm. Two anomalies that appear to be a shallow N-S cutting and a thicker “L” shaped feature have the highest archaeological potential (Figure 7a).

The third area tested was the 10-ft wide asphalt surfaced drive leading to the Waterside Theater. RT imaging shows that subsurface construction had destroyed any archaeological strata and that the area contains no features other than modern utility lines.

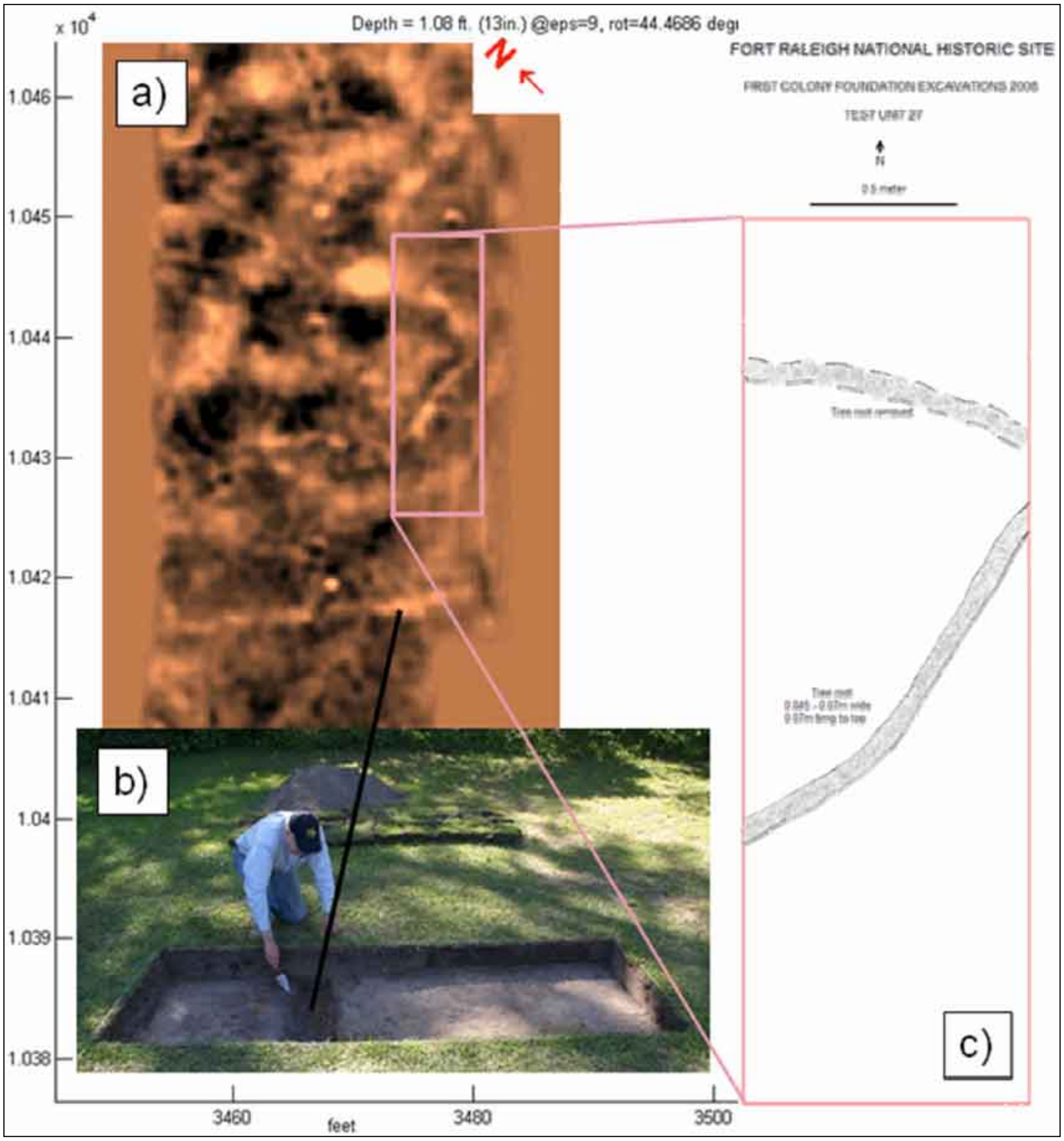

Figure 7. (a) RT 13-inch depth slice showing two anomalies that were chosen for verification by excavating small test pits; (b) FCF 2008 excavation of test unit 28 at Fort Raleigh. Excavator Ale Macdonald (yes, that is the correct spelling) indicates the east-west linear feature (small trench) recorded by RT. Photo toward west; (c) FCF 2008 excavation of test unit 27 at Fort Raleigh. Plan of excavated features (large tree roots) recorded by RT.

The final test took place in the open woodland NW of the Fort Raleigh earthwork (Figure 2). The area was surveyed N-S by an 8- to 16-ft-wide strip 200-ft long from the junction of paths at the entrance to the theater to a point west of the fort entrance, and E-W by a 16-ft-wide strip 100-ft long covering the eastern end of the Hariot Trail. This test resulted in numerous anomalies, some of which were utilities and previous excavation trenches. Those with the highest archaeological potential are at the south end of the N-S scan and the east end of the E-W scan, where excavation trenches may be found beside earlier features.

Ground Truthing

In May 2008, a FCF team directed by Eric Klingelhofer and Nicholas Luckketti opened five trenches to "ground truth" the findings of the remote sensing test survey made at FORA in January 2008 (FCF, 2008). Three locations were chosen to compare the RT anomalies with excavated features: the grassy verge west of the theater parking lot, the eastern terminus of the Harriot Trail, and an area west of the "Science Center" excavations of the 1990s. All units were excavated by shovel and trowel, with all soils below turf/humus topsoil sifted in a ¼-inch screen. Natural subsoils were tested by shovel or auger. Modern coins were deposited on the bottom of each trench, which was covered by slashed plastic sheeting and then backfilled by FORA staff.

West of the parking lot, Test Units 26, 27, and 28 measured 1 x 2 m, 1 x 3 m, and 1 x 3 m, respectively, with 1-m balks separating the units, which formed a line 3 m west of the asphalt edge. The units located modern disturbances, including the track of a bulldozer that graded the parking lot, but in Unit 28 an E-W linear feature at the position and depth (0.15 to 0.31 m below ground surface) of the RT anomaly was excavated (Figure 7b) to reveal that it was 0.16 m deep and 0.27 m wide, with a flat bottom. This cutting was identified as a probable garden feature of the Dough farm, which dated from the mid-1800s to the mid-1900s. A second RT anomaly was targeted, and this L-shaped image was found to have been made by two large tree roots (Unit 27) (Figure 7c).

Two units tested the anomalies near the "Science Center." Unit 54 (1 x 4 m), sited at the east end of the Harriot Trail, located several features that matched RT images. Sectioning revealed them to have been two post holes and one tree removal hole, all apparently recent NPS activities. No colonial artifacts were recovered. Soils here were compacted, perhaps by machinery preparing the trail. Unit 55 (1 x 5 m), lying about 10 m west of the "Science Center," revealed large roots that appeared to corroborate the RT image, as did the heavy disturbance the unit had undergone in the 20th century when this area of the then-state park may have undergone leveling and lowering.

Summary

The January 2008 RT survey at Fort Raleigh National Historic Site displayed remarkable clarity of detail. The May 2008 test of the RT survey successfully compared excavation ("ground truthing") results with RT images chosen to provide a variety of image types and soil conditions. As a result, RT has proven itself to be a remote sensing technique far superior to the standard single-channel GPR. RT has the potential to dramatically change the way in which archaeology is carried out, making much exploratory excavation unnecessary, and permitting funds to be applied to more informative archaeology.

Looking for Angola

Historical Background

In the early nineteenth century, escaped slaves and free blacks settled in southern Tampa Bay at the Manatee River, then part of Spanish La Florida. La Florida had long been a refuge from slavery and the Manatee River was one of a series of communities on the Gulf coast that maroons used in their struggle for freedom. Canter Brown, Jr. (2005) documented the Manatee River community as Angola, a haven from slave raiders after military attacks destroyed other maroon settlements farther north. Since 2005, a public archaeology program called "Looking for Angola" has sought materials for the settlement that was destroyed in 1821 as the United States took control over Florida (Baram, 2008).

There are no specific descriptions for the location of Angola, only vague descriptions of a large region. In the early nineteenth century, that region would have been dense with vegetation; today it is an urbanized landscape. Based on the archival record and analogous maroon communities, there are three special areas that are the focus of archaeological interest along the Manatee River, one of which is the Manatee Mineral Spring (Figure 5) on the property of Reflections of Manatee, Inc. Their three acres include Manatee Mineral Spring, an important source of freshwater as well as the source of legends of Native American life and Spanish exploration and the history of mid-nineteenth century village of Manatee which is now part of the city of Bradenton. Excavations faced the challenge of an abundance of nineteenth- and twentieth-century materials; RT provided a means to locate architectural finds without disturbing the extensive archaeological record of the later periods.

RT Results

The RT survey provided evidence of large number of potential architectural features on the property. Of the subsurface features, we looked at the deeper layers and the larger challenges. A cluster of dots suggested a series of postmolds (Figure 8). The depth, 82 cm, was intriguing as a possible location for a wooden structure. Rather than excavate a large area (the lessons of the standard test pits were clear to the authors), we focused on just one circle. The choice of a 1 x 2 m excavation unit over the circular feature from Angola 1 EP 7 was meant to allow the excavator to gain a close view of the level at 82 cm beneath the surface.

Ground Truthing

The crew was made up of volunteers from Reflections of Manatee, Time Sifters—the local chapter of the Florida Anthropological Society, and New College of Florida students. With less than a dozen volunteers, one excavation unit became the focus of the test in March 2008.

The excavations used 10-cm arbitrary levels to reach the target visible in the radar data as a small round dot (Figure 8). The excavation revealed a postmold (Figure 9), an organic stain in the ground that is left by a decayed wooden post. Locating a stain left in the soil where posts from a structure have decomposed is a challenge for sampling strategies in archaeology; locating a soil discoloration 82 cm below the sur-

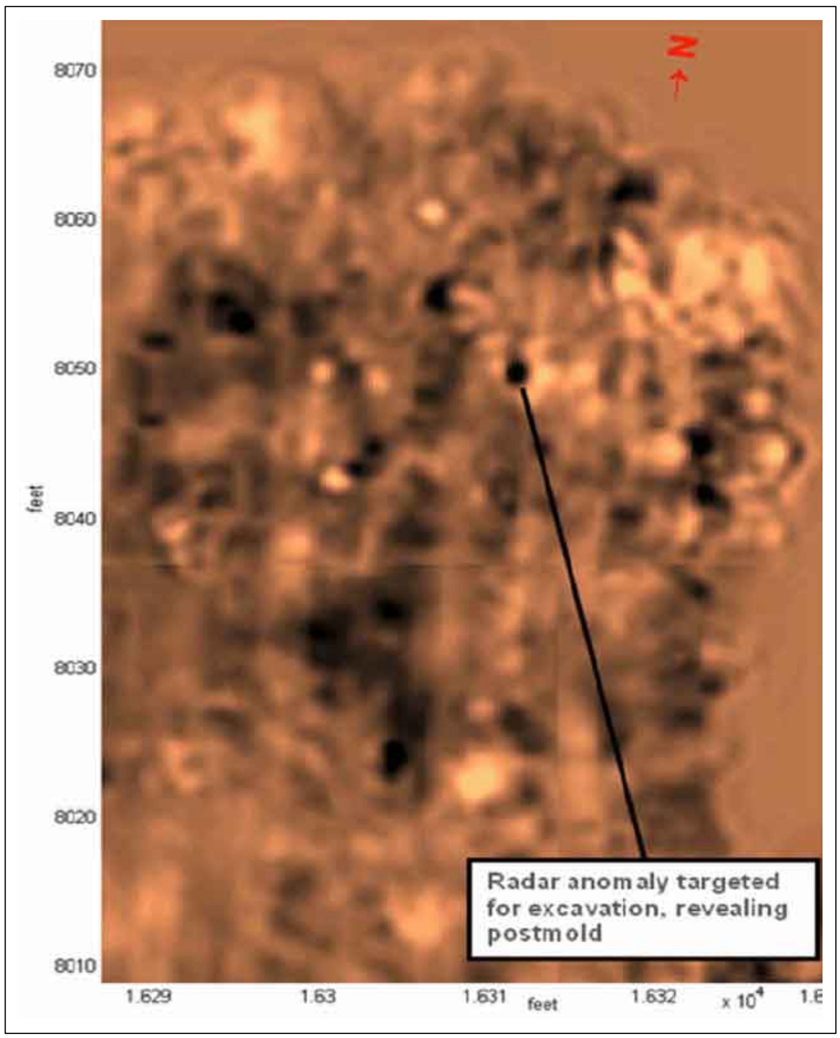

Figure 8. RT 32 inch depth slice of open field survey area, showing circular features. Anomaly indicated was excavated and revealed postmold as shown in Figure 9.

face by STP (standard test pit, the standard invasive archaeological technique used to survey areas) is unlikely. The survey opened up a deeply buried cultural landscape, with precision.

The wooden post, in the context of the other features seen by the survey, suggests a structure of some sort. The assumption focuses on a basic construction technique that involves placing support posts in the ground to create a frame, and then using other materials (branches, palm fronds, or other possibilities) to enclose the structure. Archaeologists recognize that when wooden posts deteriorate or burn, they leave a stain in the soil that indicates where the original posts were located.

Figure 9. Excavation unit for Looking for Angola at Reflections of Manatee, Inc. The unit revealed a postmold. Photograph by Uzi Baram.

Summary

As a test of the radar tomography survey, this excavation was a success. A subsurface feature was located with RT and excavations showed it was a postmold, a feature otherwise not visible with other non-invasive surveying. The depth of the find, and similar information from the RT survey in the immediate area of the excavation unit, is suggestive of architecture from one of the past landscapes of the region.

More excavations are needed to identify the feature and to establish a reasonable age, but with many features showing in the 3D radar images, there are a host of possible excavations across the property representing different possible structures and past cultural landscapes. This changes the approach of archaeologists to focus on small excavation areas rather than larger excavations without guidance through a technology such as RT.

On the broader level, the test demonstrated the need to recognize the location of the plentiful subsurface material remains at Reflections of Manatee, Inc. Locating the postmold required removing several cultural levels, with many artifacts. A broad excavation would have produced an abundance of materials for analysis and curation. The testing indicates that RT was successful and can be an important tool for effective archaeological research.

Since Looking for Angola is a public program that makes its decisions regarding research in the Florida sunshine and reaches out to communities for their feedback and their support of archaeological excavations, the survey and excavations were open to the public. For the test excavations, the team invited the local media to interview the participants and watch the proceedings. Reporters from the AP, Bradenton Herald, Sarasota Herald-Tribune, and WUSF came to the excavation. The media became a means to share the process and results with a wide audience (the AP story was distributed nationally).

Conclusions

The tests of both RT surveys successfully compared "ground truthing" results with RT images chosen to provide a variety of image types and soil conditions. As a result, RT has proven itself to be a remote sensing technique far superior to single-channel GPR.

RT has the potential to dramatically change the way in which archaeology is carried out, making much exploratory excavation unnecessary, and permitting funds to be applied to more informative archaeology. Large excavations may be replaced by many small excavations guided by anomalies identified in high-resolution GPR images created with RT. It may offer archaeologists here and elsewhere an improved tool for identifying areas for excavations with a higher chance of return.

Acknowledgments

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Rediscovering Ancient Earthwork Complexes in Ohio with Geophysics

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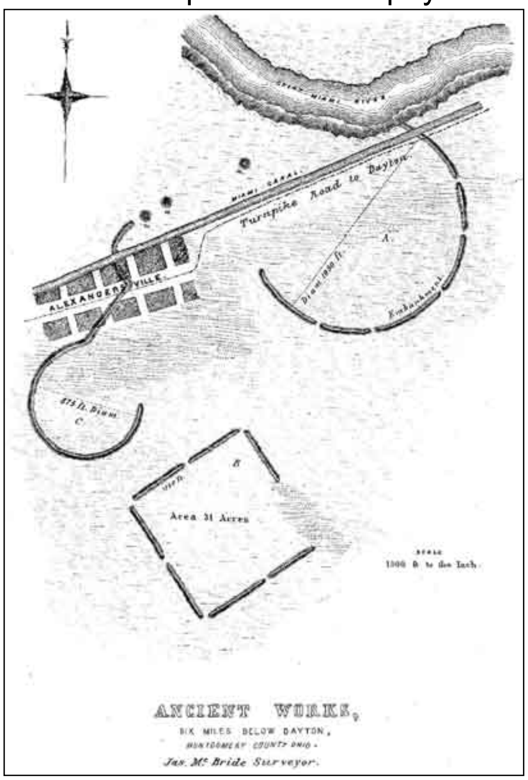
Two thousand years ago, Native Americans in the Middle Ohio Valley built many hundreds of earthwork complexes. Ohio, predominantly in the southern part of the state, is especially rich with these earthwork sites, boasting over 600 of them. Erosion and the last two hundred years of plowing have made some of these earthworks invisible at the surface. Of course, their ability to detect the near invisible is exactly why archaeologists, like me, have begun using geophysical survey instruments to search for and document Ohio's past. And the payoff for all those hours spent listening to the beeping of the instruments and walking countless miles collecting data has been quite worth the effort in the case of Ohio's earthwork sites.

Earthworks are linear embankments and ditches in the forms of circles, squares, octagons, and many other shapes. These earthen monuments were built by hand, basket load by basket load. Small circular enclosures, from 20 to 90 meters across, are the most common and probably the earliest constructed—perhaps as early as 100 BC. By AD 200-300, the newer earthworks were being built on a truly monumental scale, with circles and octagons well over 300 meters in diameter. The larger earthworks, like the Great Circle at Newark and the Fort Ancient site near South Lebanon, had embankment walls six or seven meters tall. While some of the earthworks are known to have been used as calendar systems for marking the movement of the moon and perhaps the sun, the exact function of these enigmatic monuments of earth may never be known. Many earthwork sites include mounds under which some of a community's dead were buried, but there are plenty of earthwork sites that were not apparently used as cemeteries. Almost none of these sites contains significant signs of day-to-day life, in the form of everyday trash. Thus, it is likely that the earthworks served a more ceremonial or ritual purpose, a place for communities and families to gather and to participate in important ceremonies, feasting, and many other activities.

Being so large and in some cases complex in their geometry and layout, earthworks have been a focal point of interest ever since the first



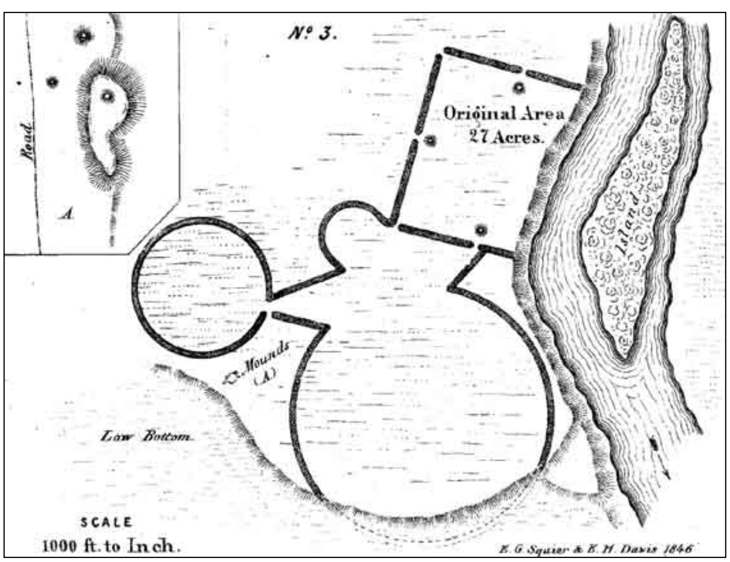


Figure 1. Two maps of Ohio earthwork sites from Squier and Davis's 1848 volume—both of these earthworks have been destroyed by urban development. Upper map: Alexandersville Works near Dayton, Ohio. Lower map: Works East, Chillicothe, Ohio.

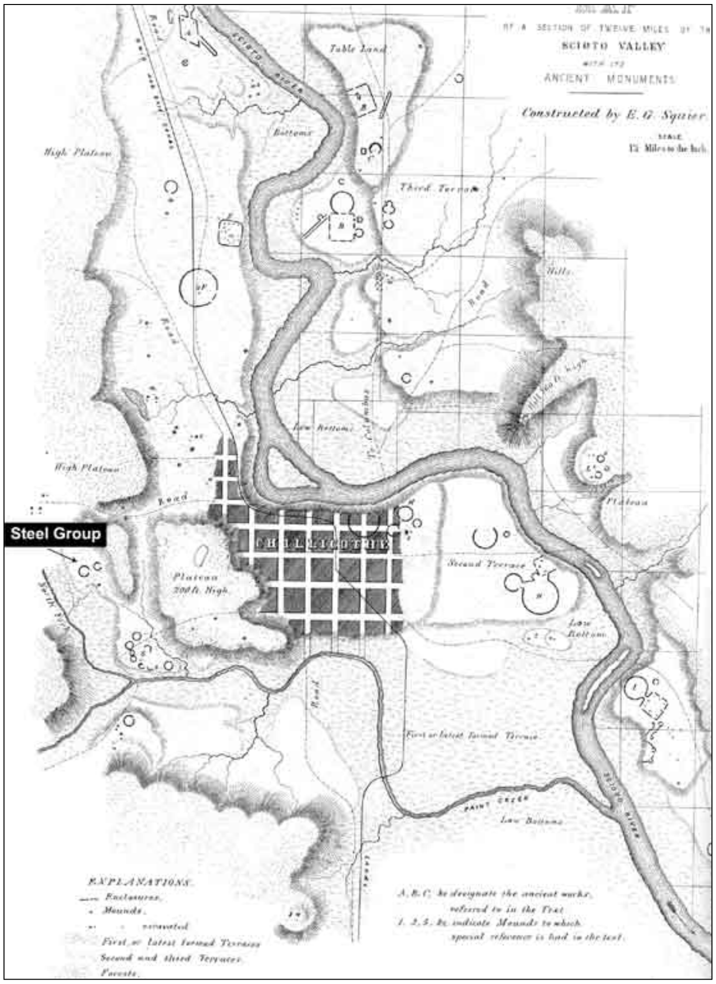


Figure 2. Squier and Davis's (1848) map of earthworks in the Chillicothe area, showing the location of the Steel Group site.

Euro-Americans began to traverse what is now Ohio. The first maps of some of the earthwork sites were made in the late 1700s, and by the mid 1800s books like Ancient Monuments of the Mississippi Valley, written by Ephraim Squier and Edwin Davis, contained detailed maps of over 80 sites in Ohio. The maps in Figures 1 and 2 (from Squier and Davis, 1848), depicting Works East and Alexandersville, exhibit two classic earthwork complexes from southern Ohio that were mapped in the 1840s—both of these have since been erased from the landscape by urban development. Regrettably, less than two dozen of Ohio's earthwork complexes are protected in parks (for example, Hopewell Culture National Historical Park, in Chillicothe). The exact locations of many of the remaining 500-plus sites have been lost to time and the plow.

A couple years ago I had the good fortune to be contacted by a landowner in Ross County, Ohio who owned one of the more modest earthwork sites depicted in Squier and Davis's 1848 volume. Though not named in their volume, this site is now known as the Steel Group. In a famous map in their book (Figure 2), Squier and Davis (1848: Plate 2) show a twelve-mile section of the Scioto River Valley around the town of Chillicothe, an area famous for its many earthworks, and squeezed in on the left hand side of the map are the two small, apparently circular, enclosures of the Steel Group. Having worked for some years at the nearby national park that contains earthworks, I was well aware of the circles at the Steel Group and, since moving on to the private sector, had wondered how I might gain access to the site to conduct a geophysical survey. The unexpected phone call and invitation to survey the earthworks was seemingly providential! At this point I should mention that I am an archaeologist, trained in the traditional ways of trowel-and-shovel archaeology. While in graduate school at Ohio State University, our Anthropology department purchased a magnetometer—the FM 36 fluxgate gradiometer made by Geoscan Research. Unfortunately, there was no one in our department to teach us how to use this instrument, so a group of us graduate students taught ourselves. From these early experiences with geophysics, I was so convinced of the importance of integrating geophysical survey into archaeology projects on a regular basis that I talked a friend of mine into buying a magnetometer for his contract archaeology business, with the promise that I would come work for him after graduation (contract archaeologists work in the private sector and help clients comply with federal and state laws that require archaeological study be done ahead of certain development projects). I now conduct geophysical surveys (magnetic gradient, electrical resistance, and radar, primarily) on all kinds of work-related archaeology sites, and in my spare time I seek out earthwork sites in need of survey.

Figure 3. Aerial view of the Steel Group in June 2007.

In the summer of 2007, an archaeology research group of which I am a member rented a helicopter and pilot for a couple of hours to take aerial photographs of our excavations at a prehistoric settlement south of Chillicothe. On the way back from taking my photographs, I asked the pilot to swing by the Steel Group site, knowing that I would be beginning my magnetometer survey there later in the year and that some aerial photographs might be useful. Much to my delight, the field in which the Steel Group earthworks are located was planted in wheat that year, and, being early June, the wheat was just starting to turn brown. This is perhaps the most ideal time and crop cover for seeing earthworks in agricultural fields, because the wheat growing over the ditches of the earthworks remains green as all of the other wheat first starts to turn brown. The photo in Figure 3 is one of the aerial shots of the Steel Group I was able to snap as we banked by the site in the helicopter. The two enclosures shown on the Squire and Davis map are clearly visible, and I have marked them with the numbers 1 and 2. Also evident are a number of what look to be additional enclosures, previously undocumented, and these I have marked with little blue arrows. To say that I was surprised to see all of the new possible enclosures in the photographs is an understatement. It is not every day that an archaeologists finds so many new and undocumented earthworks, especially not in Ross County, Ohio, where archaeologists and scholars have been studying the earthworks for nearly 200 years.

In October 2007 I began the magnetic survey at Steel Group (Figure 4) using a fluxgate gradiometer—the FM256 model made by Geoscan Research. This instrument only records the magnetic gradient (not the total field) between its two sensors, which are spaced 50-cm apart. Because of the size of the sites we usually study and the way in which the geophysical instruments are set up to collect data, archaeologists in the U.S. tend to collect geophysical data in 20 x 20 meter blocks, which

Figure 4. Jarrod Burks at the Steel Group site holding the FM256 fluxgate gradiometer and speaking with one of the landowners about the earthworks.

are then stitched together in a software package and the whole of the dataset processed through a variety of algorithms. At Steel Group I covered 240 blocks, or about 24 acres. The instrument was set up to collect eight readings per meter along transects spaced one meter apart. At this data density I can cover about three acres per day, including setting up the block corners with a laser transit. Since I may want to conduct some excavations at a future date, it was important to collect the magnetic data in a very controlled fashion and have it all tied in to semi-permanent mapping points that can be used to re-establish the survey grid in a very accurate way — using the laser transit makes this easy. While geophysical surveying is fast, archaeological excavation is not, so it is important to dig in the right place and with excavation units that are as small as possible to get the job done.

The results of the magnetic survey appear in Figure 5, overlain on a 1994 aerial photograph. Squier and Davis mapped just two enclosures at this site in 1845. In fact, there are at least ten embankment and ditch enclosures apparent in the magnetic data collected to date. The original enclosures are marked with a #1 and #2. Each of the enclosures appears in the data as a dark inner feature surrounded by a lighter, kind of fuzzy area. The dark inner portions of these enclosures are the ditches. Since the ditches have filled back in with topsoil and some of the original embankment fill, they appear as positive magnetic anomalies—the ditches are more magnetic than the surrounding soil. This is not too surprising since topsoil is magnetically enhanced and when it occurs in thicker deposits, either in ditches below surface or as plow ridges at the surface, it creates positive magnetic anomalies. The lighter colored, fuzzy areas surrounding the in-filled ditches are the remains of the embankment walls. Since these once above-ground features are now so flattened that they are not evident at the surface (except for enclosures #1 and #2), why are they even present in the magnetic data? One possibility is that the ground on which the embankments was to be constructed was first stripped of its topsoil, and then the soil for the embankments was piled directly onto the subsoil. The lack of topsoil would cause the area of the

Figure 5. Results of the magnetic gradient survey at Steel Group.

embankments to appear as less magnetic in the survey data. Another possibility is that the soil used to create the embankments was clay, and clay is typically less magnetic than topsoil. Though plowed flat, this clay is still present in the plow layer and is making it less magnetic. More than likely, it is a combination of both of these explanations — the topsoil was removed first and then clay was piled up to form the embankments. Together, these factors are what make the embankments appear less magnetic in magnetic gradient survey data.

As an archaeologist who studies prehistoric earthworks in Ohio, I will have to admit that every time I see the Steel Group results I can't help but think to myself what else might be out there, just waiting for a magnetometer or electrical resistance meter to find it? Some months before surveying at Steel Group, I was helping a friend survey a prehistoric village site near Columbus, Ohio that is about 800 years old. As we were detecting the magnetic signatures of buried trash pits and cooking pits, we accidentally detected a ditch and embankment enclosure at the edge of the village. This was an earthwork that nobody knew was even there — it had never been seen in any aerial photos and it had eluded the nineteenth- and early twentieth-century earthwork mappers. How many more unknown earthworks could there be in Ohio?

I once thought that we are incredibly lucky that people in the 1800s were interested enough to map the earthworks, because today most of the earthworks have been so plowed down that they are invisible and we can no longer map them through conventional means. Without those nineteenth century maps, we would be unaware of the locations and shapes of at least 90 percent of Ohio's earthworks since they are no longer visible. Now, with the help of speedy (digital) near-surface geophysical survey instruments and powerful data processing software, the results from the Steel Group survey show us that the process of mapping Ohio's earthworks has only just begun. It is time to trade in the surveyors chains and compasses for the beeping and clicking of today's geophysical instruments. For the sake of my knees and back, I just hope that tomorrow's more affordable instruments are self-propelled . . .

References

Squier, Ephraim G., and Davis, Edwin H., 1848, Ancient monuments of the Mississippi Valley: Contributions to Knowledge 1: Smithsonian Institution Press, Washington.

For additional information on Ohio's prehistoric past and earthworks, see:

Lepper, Bradley T., 2005, Ohio archaeology: An illustrated chronicle of Ohio's ancient American Indian cultures: Orange Frazer Press, Wilmington, Ohio.

Woodward, Susan L., and McDonald, Jerry N., 1994, Indian mounds of the Middle Ohio Valley: A guide to Adena and Hopewell Sites: The McDonald and Woodward Publishing Company, Blacksburg, Virginia.

Hopewell Culture National Historical Park: www.nps.gov/hocu/

The Ohio Historical Society: www.ohiohistory.org

The Ohio Archaeological Council: www.ohioarchaeology.org

For additional information on the Steel Group survey, see:

www.ohioarchaeology.org/joomla/index.php?option=com_content&task=view&id=236&Itemid=32

Near-Surface Community News

***FastTIMES** publishes contributions from societies and individuals with an interest in near-surface geophysics. Representatives of the Near-Surface Focus Group of the American Geophysical Union contributed the item below. Contributions from others are always welcome.*

Near Surface Geophysics (NS) Enters Its Second Term

The second term of the American Geophysical Union (AGU) focus group in Near Surface Geophysics (NS) began July 1, 2008. With Rosemary Knight (Stanford University) serving as chair for the first term, the focus group grew rapidly, currently having about 2200 members with 538 of these members declaring NS as their primary affiliation within AGU. Lee Slater (Rutgers University) is serving as Chair for the second 2-year term, with Louise Pellerin (Green Engineering) serving as Vice-Chair and George Tsoflias (Kansas University) serving as Secretary. They will be closely assisted by a new Executive Committee, the members being (in addition to the Chair, Vice-Chair and Secretary): [1] Sarah Kruse (University of South Florida), Fall Meeting Program Representative (to be replaced '09); [2] Chester Weiss (Virginia Tech), Spring Meeting Program Representative (to be replaced '09 with Rosemary Knight); [3] Niklas Linde (University of Lausanne), European Representative and Liaison to European Groups (European Association of Geoscientists & Engineers (EAGE), European Geosciences Union (EGU)) as well as AGU Hydrogeophysics; [4] Sue McGeary (University of Delaware), Liaison to Geological Society of America (GSA), Environmental and Engineering Geophysical Society (EEGS) and other AGU Sections/Focus Groups; [5] Rhett Herman, Webmaster.

The NS Focus Group plans to run six special sessions at the Fall AGU Meeting in San Francisco (December 15–19). These sessions will cover new applications of geophysics in stratigraphic imaging, geophysical characterization of flow/transport in dual porosity media (fractures and glaciers, for example), new advancements in joint inversion methods and monitoring strategies for imaging coupled thermo-hydro-mechanical processes in the earth. The NS focus group is also sponsoring three topical sessions organized by the Hydrogeophysics Committee of the AGU Hydrology Section. For further details see the scientific program at www.agu.org/meetings/fm08/?content=program.

NS is also sponsoring the upcoming AGU Chapman Conference in Biogeophysics. AGU describes Chapman Conferences as "small, highly focused meetings that provide significant time for discussion and interaction among the participants." The AGU Chapman Conference on Biogeophysics, October 13–16, promises to be a unique, workshop-environment meeting of microbiologists and geophysicists to discuss opportunities within this emerging interdisciplinary field that considers how geophysical methods might be applied to image microbial processes in the Earth. The meeting will include about 45 presentations, including plenary talks by three highly distinguished biogeochemists, and evening poster sessions spread over 3.5 days. Full details of the plenary talks and invited speakers for the four topical oral sessions can be found at www.agu.org/meetings/chapman/2008/fcall/. As a result of a generous grant from the National Science Foundation, limited travel funds are available for early career scientists (within 7 yrs of Ph.D.) and students to participate in this meeting. Contact Estella Atekwana (atekwana@umr.edu) for more information.

NS is committed to broadening communication between near-surface geophysics groups and societies. You will hear from NS on a regular basis and we look forward to your input. To learn more about NS activities visit the NS website at www.agu.org/focus_group/nsg/index.html.

Coming Events

__FastTIMES__ highlights upcoming events of interest to the near-surface community. Send your submissions to the editors for possible inclusion in the next issue.

24th Annual International Conference on Soils, Sediments and Water

Analysis, Site Assessment, Fate, Environmental and Human Risk Assessment, Remediation and Regulation
University of Massachusetts at Amherst, October 20-23, 2008

Conference Directors: Paul T. Kostecki, Edward J. Calabrese, and Clifford Bruell

The annual Conference on Contaminated Soils at the University of Massachusetts at Amherst is the preeminent technical national conference in this important environmental area. This annual conference consistently attracts over 800 attendees from across the United States as well as from Canada and other foreign countries. Attendees include a wide variety of representation from state and federal agencies; military; industries including railroad, petroleum, transportation, utilities; the environmental engineering and consulting community; and academia.

This year's conference will offer exciting opportunities for all those concerned with the challenge of developing creative, cost-effective assessments and solutions that can withstand the demands of regulatory requirements. There will be a strong and diverse technical program in concert with a variety of educational opportunities. The exhibition section brings the real-world application to the technical theory and case studies, which will be presented in the platform and poster sessions. Focused workshops will provide attendees with the type of practical application information, which will impact their job performance immediately. More information is available at www.UMassSoils.com.

Near-Surface Geophysics at the 2008 SEG Annual Meeting

November 9–14, 2008, Las Vegas, Nevada

The Near Surface Geophysics Section of the Society of Exploration Geophysicists (SEG) invites you to attend the 2008 SEG International Exposition and 78th Annual Meeting in Las Vegas, Nevada, November 9–14, 2008. Advance registration is now open; visit www.seg.org for meeting details. If you have any questions please do not hesitate to email Rob Jacob (Robert_Jacob@brown.edu).

There are multiple Near Surface Geophysics (NSG) events planned for the 2008 SEG meeting, including a shindig fit to celebrate the NSGS 15th anniversary. This year, the SEG Forum Series will kick off the SEG Technical Program, with a focus on hydrogeophysics, where top executives, researchers, and governmental representatives provide their perspectives on the future direction of using geophysics to better characterize our groundwater resources, leading to better management of our groundwater supplies. In addition to the several near-surface and environmental technical sessions, the NSGS is sponsoring two special sessions at SEG 2008: Hydrogeophysics in Practice and UXO Detection.

Students are encouraged to apply for one of the multiple NSGS $500 travel grants to attend SEG 2008. See nsgs.seg.org/travelg.htm for details. If you are not a member of the SEG-NSG Section, please consider joining (nsgs.seg.org/join.htm). NSG Section membership is only $15 (free to students), and SEG membership is not required.

EEGS-NSGS Workshop on Induced Polarization: Research and Recent Advances in Near-Surface Applications

November 14, 2008, SEG Annual Meeting, Las Vegas, Nevada, USA

The Environmental and Engineering Geophysical Society (EEGS) and the Society of Exploration Geophysicists, Near- Surface Geophysics Section (SEG-NSGS) invite you to a jointly sponsored workshop on induced polarization (IP) to be held following the 2008 SEG Annual Meeting in Las Vegas, Nevada. Scientists and engineers will come together to share research and near-surface application of IP to diverse environmental, hydrological, and engineering problems, including infrastructure assessment.

The workshop will begin with a short historical and tutorial discussion of IP, followed by technical sessions on:

(1) Recent Research in IP Data Acquisition,

(2) Rock Properties, Theory and Laboratory Studies of IP,

(3) Inverse Modeling and Imaging of IP Data, and

(4) Near Surface Applications of IP

and conclude with a discussion and summary.

Organizers

Esben Auken, The HydroGeophysics Group, University of Aarhus, Denmark esben.auken@geo.au.dk;
Douglas J. LaBrecque, Multi-Phase Technologies, Sparks, Nevada USA dlabrecque@mpt3d.com;
Lee Slater, Earth & Environmental Sciences, Rutgers University-Newark, New Jersey USA lslater@andromeda.rutgers.edu

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Increasing the Societal Impact of Geophysics

Public Affairs Session 02, Fall Meeting of the American Geophysical Union (AGU), San Francisco, California, December 15–19, 2008

Geophysics is a field that benefits society in numerous ways that include the exploration and production of resources, the prediction and mitigation of natural hazards, the characterization of hydrological systems, and a better quantitative understanding of the way in which our environment works. In this session we present various initiatives that aim at increasing the societal impact of geophysics. There are an impressive number of initiatives within the geoscience community that have the goal to use geophysics for solving environmental, geotechnical and hydrological problems, or that help manage natural hazards and resources in impoverished regions. By presenting such initiatives we hope to engage more geophysicists in humanitarian activities.

This session (PA02) will bring together a group of dedicated, interesting people. We hope that you will join us. See www.agu.org/meetings/fm08/ for more information.

Organizers

Roel Snieder, Colorado School of Mines, Golden, Colorado, rsnieder@mines.edu;
Louise Pellerin, Green Engineering, Inc., Berkeley, California, pellerin@ak.net

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22nd Symposium on the Application of Geophysics to Engineering and Environmental Problems

March 29–April 2, 2009, Fort Worth, Texas

The Environmental and Engineering Geophysical Society (EEGS), general chair Doug Laymon, and technical chair Dwain Butler invite you to attend the 22nd Annual Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) being held at the Renaissance Worthington Hotel in downtown Fort Worth, Texas. Fort Worth is a city filled with culture and western heritage and is known as the city "Where the West Begins." Fort Worth has much to offer and enjoy including the historical stockyards, great museums, an exciting downtown, wonderful restaurants, and fun nightlife in the Sundance Square area.

So save the dates on your calendar for March 29 through April 2, 2009 and plan to submit an abstract for the 2009 meeting. The SAGEEP 2009 theme is "Expanding Horizons for Near-Surface Geophysics." Abstracts that focus on recent developments in near-surface geophysical methods, innovative uses of geophysics for challenging engineering and environmental problems, and case histories are welcome.

Special sessions for SAGEEP 2009 include:

- *Cavities and tunnels: Chaired by Jeff Daniels and Russell Harmon*
- *Agricultural geophysics: Chaired by Barry Allred*
- *Humanitarian water supply geo-engineering: Chaired by Catherine Skokan*
- *NGWA special session: Chaired byJohn Jansen*
- *Geophysics and the Ogallala Formation: Chaired by Wade Kress and Gregory Stanton*

Abstracts not to exceed 200 words are due no later than October 3, 2008 and may be submitted electronically at www.eegs.org. If accepted, full manuscripts will be due December 12, 2008.

New for 2009: Student Poster Session!

SAGEEP 2009 will highlight student research and applications in a special ***Student Poster Session***. To be considered for this inaugural Student Poster Session, an abstract (not to exceed 200 words) is required. Deadline for the student session abstract submission is December 12, 2008 and the $50 abstract fee is required at time of submission.

In addition to the technical presentations, other SAGEEP 2009 activities will include field trips, short courses, workshops, and networking opportunities. For the latest information about SAGEEP 2009, visit the conference web site at www.eegs.org/sageep/. To become involved, please contact SAGEEP 2009 General Chair Doug Laymon at doug.laymon@tetratech.com.

Near-Surface Geophysics Special Sections in The Leading Edge

by Richard D. Miller, Editorial Board Member, ***The Leading Edge*** (rmiller@kgs.ku.edu)

As many of you are aware, the Society of Exploration Geophysicists' magazine, ***The Leading Edge*** (***TLE***), publishes special sections each month highlighting emerging or active areas of applied geophysics. In the coming months, the near-surface community will have several opportunities to enlighten the entire geophysical community on the high quality and innovative nature of their work. Over the next year or so special sections on "near surface" and "hydrogeophysics" have been placed on the editorial calendar to provide opportunities to emphasize the use geophysics to solve near-surface problems. "Near Surface" is scheduled for publication in November 2008 and "Hydrogeophysics" is scheduled for the October 2009 issue of ***TLE***. The deadline for papers to be considered for the Hydrogeophysics special section is June 2009. If you have any comments, questions, or would like to submit a paper, please contact Rick Miller at rmiller@kgs.ku.edu.

Multiple Hires in Earth Surface and Hydrologic Processes

Jackson School of Geosciences, The University of Texas at Austin

The Jackson School is building a premier education and research program in Earth Surface and Hydrologic Processes. We seek outstanding scientists at the forefront of their disciplines who are attracted to challenging areas of scholarship that require collaboration across disciplines and programs. We seek to address compelling questions in surface and hydrologic processes within the broad theme of determining how surface and hydrologic processes are influenced by their dynamic setting at the interface of the lithosphere, atmosphere, hydrosphere, and biosphere.

Over the next three years, the Jackson School plans to hire six or more faculty and scientists who complement our existing strengths. We are interested in a range of research areas from quantitative geomorphology to hydrologic-biologic interactions to societal impacts and resource sustainability, and capabilities ranging from modeling landscape dynamics to remote sensing, near-surface geophysics, aerogeophysics, and monitoring groundwater and coastal systems. We also encourage innovative scientists in other areas related to surface and hydrologic processes to apply. More information can be found at www.jsg.utexas.edu/hiring/hydro.html.

FastTIMES Editor-in-Chief

Environmental and Engineering Geophysical Society

The Environmental and Engineering Geophysical Society seeks candidates to serve as Editor-in-Chief for ***FastTIMES***, the society's quarterly electronic newsmagazine for the near-surface geophysical community. Preferred qualifications include (a) broad knowledge of near-surface geophysical methods, (b) willingness to solicit article contributions, (c) facility with electronic publishing tools including Adobe Photoshop and InDesign, (d) willingness to participate in monthly EEGS Board of Directors conference calls and meetings, (e) membership in EEGS, and (f) a commitment to on-time publication of four issues per year. Interested candidates should contact President Jon Nyquist (nyq@temple.edu).

Inverse Modeling Post-doctoral Opportunity at USGS Denver

Development of Joint Inverse Methods for Improved Characterization and Assessment of Groundwater, Mineral, and Petroleum Resources

In geophysical imaging and groundwater or petroleum reservoir model calibration, inverse methods typically use a single type of data sensitive to a single physical property. Combining several types of data collected over the same region can reduce ambiguity and enhance inversion results. Combining different data types into an inversion can be important when relationships exist between the different property distributions. By inverting each data set individually, the recovered physical property models may be inconsistent with prior knowledge regarding relationships. Cooperative strategies may be employed to ensure consistency between the different models, but the models obtained are often biased towards the result of the first inversion or the survey with greater sensitivity. Another approach is to fit the data sets simultaneously in a joint inversion. Many investigators perform simultaneous inversions of data from different surveys sensitive to the same physical property. Others jointly invert data sets responsive to different physical properties between which there is an analytic relationship. However, little work has focused on the joint inversion of disparate data sets when there is no analytic relationship available between the properties. Research on the joint inversion of disparate data sets is likely to reveal new challenges regarding parameterization, potential inconsistencies between the data sets, relative weighting issues, and the introduction of an estimation bias due to increased systematic errors.

The focus of this Research Opportunity is developing joint inverse strategies for improved characterization and assessment of groundwater, mineral, and petroleum resources. This research opportunity will promote development through the integration of geologic, geophysical, and hydrogeologic information as measurement constraints during the simultaneous solution of multiple numerical models. Because the focus of this project is on the development of integrated joint inverse methods rather than a specific application, the scale and direction of research is to be determined by the postdoctoral fellow.

One example would be the joint inversion of gravity and magnetic responses over a draped surface to estimate the 3-dimensional geology using a Markov Monte Carlo approach. A second example would be the joint inversion of airborne and ground-based electromagnetic responses together with borehole geophysical and hydrogeologic mass and energy measurements to define a coastal fresh-salt water interface using a Levenberg-Marquardt approach. A third example would be the joint inversion of surface and borehole dc resistivity and spontaneous potential response together with subsurface variably saturated zone measurements to estimate ground-water recharge using a combination of genetic algorithm and Levenberg-Marquardt approaches. In these cases, special attention will be on the development and evaluation of an appropriate regularization strategy, as well as the estimation of uncertainty in model parameters and prediction of dependent variables. Regularization strategies could involve one or more analytical, petrophysical, and structural constraints applied as direct or soft prior information. Understanding the worth of combined information on reducing model and predictive uncertainty is an expected outcome of this research.

For more information, visit *http://geology.usgs.gov/postdoc/2010/opps/opp21.html* or contact Michael Friedel, U. S. Geological Survey, Denver, Colorado, (303) 236-7790, *mfriedel@usgs.gov*.

The EEGS / Geonics Early Career Award

Nomination Deadline: October 31, 2008

The Environmental and Engineering Geophysical Society and Geonics Limited are pleased to announce that nominations are now open for the 2009 EEGS / Geonics Early Career Award, which acknowledges academic excellence and encourages research in near-surface geophysics. The award is presented annually at SAGEEP to a full-time university faculty member who is within ten years post-completion of his or her PhD. The award acknowledges significant and ongoing contributions to the discipline of environmental and engineering geophysics. The recipient may have any specialty that is recognized as part of the environmental and engineering geophysics discipline. This specialty is not restricted to departments, colleges, or geographic regions (international applicants are welcome). A committee of five members (three university faculty, one corporate or consulting representative, and one government laboratory representative), appointed by the EEGS Board, is responsible for selecting the awardee.

The award carries the following benefits:

- *Free registration to the SAGEEP conference at which the award will be presented*
- *A plaque, suitable for display*
- *A $1000 cash award*
- *A 45-minute time slot to present the awardee's research and vision at SAGEEP*
- *The citation and, if available, the awardee's presentation, is published in* ***FastTIMES*** *and distributed to cooperating societies*

The awardee will be expected to be present during the technical core of SAGEEP 2009 in Fort Worth, Texas (Sunday evening, March 29 through Wednesday afternoon, April 1, 2009). Nominations should be sent electronically to:

Dr. Roger Young, Chair of the Early Career Award Committee
ConocoPhillips School of Geology and Geophysics, Sarkeys Energy Center
University of Oklahoma
100 E. Boyd Street. Norman, OK 73019
ryoung@ou.edu

Nomination packages must include:

- *A comprehensive vitae for the candidate*
- *A letter of recommendation outlining the candidate's qualifications for the award*
- *Copies or pdf files of three representative publications*

The deadline for submission of nominations is October 31, 2008. Questions should be directed to Dr. Young at the address listed above.

Join EEGS Now!

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

Membership Information

EEGS welcomes membership applications from individuals (including students) and businesses. The membership application is available from the EEGS office or online at www.eegs.org.

Individual $90

Member receives annual subscriptions to ***JEEG*** and ***FastTIMES*** along with discounts for EEGS publications, SAGEEP registration, and other EEGS functions.

Student $50

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