fast | times

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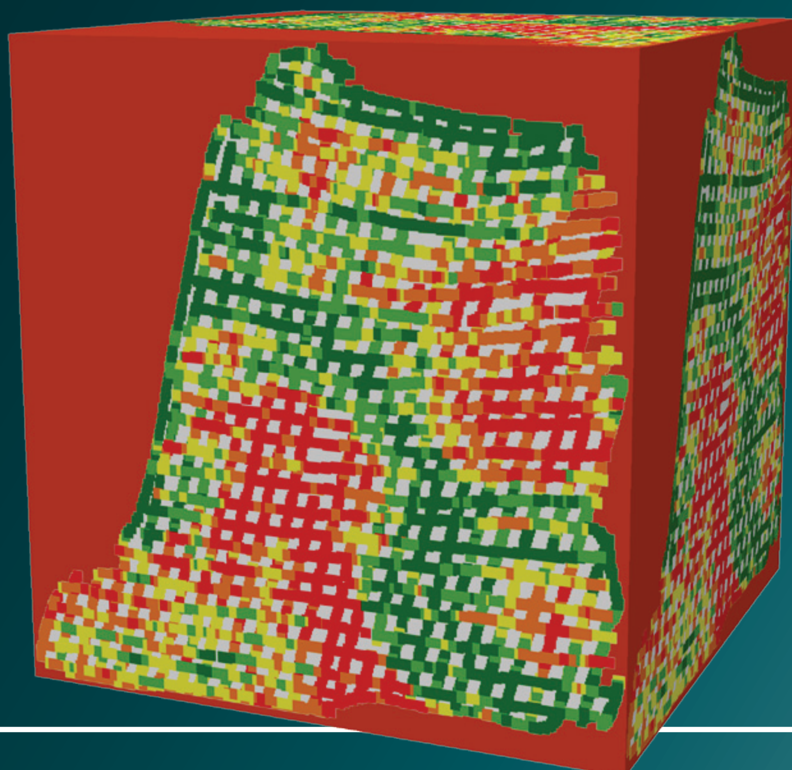
PROXIMAL SOIL SENSING



In this issue . . .

- Special Issue of JEEG: TDEM
- SEG-AGU Hydrogeophysics Workshop
- Gamma Ray Soil Sensor
- SAGEEP's Silver Anniversary

. . . and more!

The Mole

On the Cover

This issue features the development and application of geophysical techniques to proximal soil sensing. Cover image shows the raw soil reflectance map developed by Eric Lund.

What We Want From You

The ***FastTIMES*** editorial team welcomes contributions of any subject touching upon geophysics. The theme for our next issue will be the development and application of electroseismic techniques. ***FastTIMES*** also accepts photographs and brief non-commercial descriptions of new instruments with possible environmental or engineering applications, news from geophysical or earth-science societies, conference notices, and brief reports from recent conferences. Please submit your items to a member of the ***FastTIMES*** editorial team by May 21, 2012 to ensure inclusion in the next issue. We look forward to seeing your work in our pages.

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Contents

Click on the titles to read the article.

FastTIMES

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

About EEGS

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

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

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

Joining EEGS

EEGS welcomes membership applications from individuals (including students) and businesses. Annual dues are currently $90 for an individual membership, $50 for a retired member $20 for a student membership, $50 developing world membership, and $650 to $4000 for various levels of corporate membership. All membership categories include free online access to JEEG. The membership application is available at the back of this issue, or online at www.eegs.org. See the back page for more information.

FastTIMES Submissions

To submit information for inclusion in ***FastTIMES***, contact a member of the editorial team:

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Jackie Jacoby
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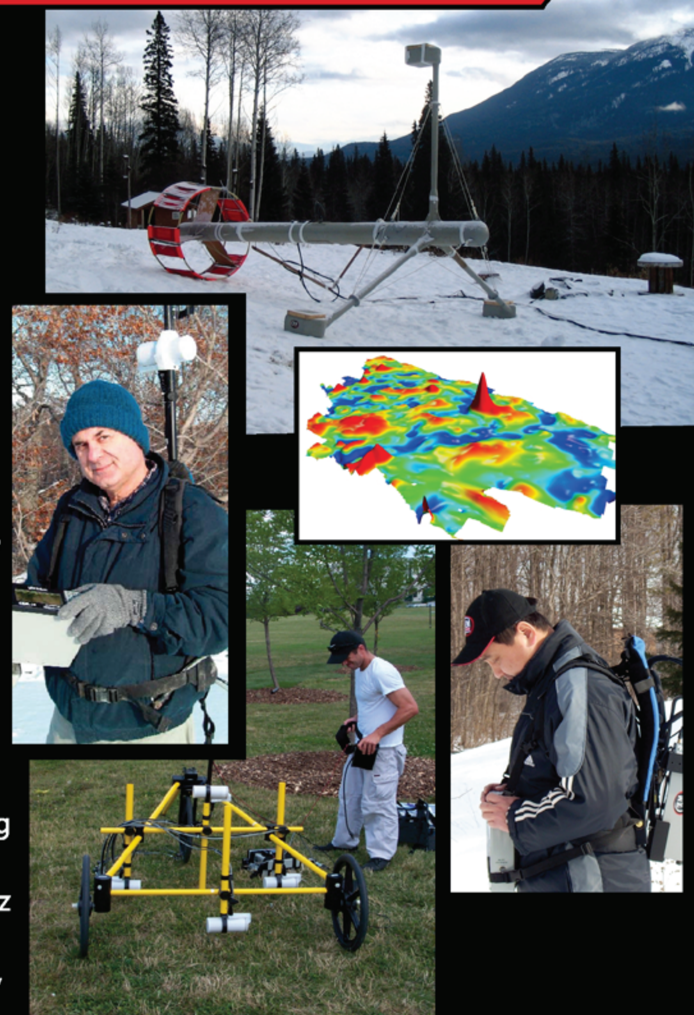
FastTIMES is published electronically four times a year. Please send articles to any member of the editorial team by November 21, 2011. Advertisements are due to Jackie Jacoby by November 21, 2011.



Calendar

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

2012

March 5-8	DGG Meeting 2012 in Hamburg 72nd annual meeting of the German Geophysical Society, celebrating its 90th anniversary, Hamburg, Germany
March 25-29	25th Anniversary Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) "Making Waves: Geophysical Innovations for a Thirsty World", Tucson, AZ
May 21	Deadline for submission of articles, advertisements, and contributions to the June issue of *FastTIMES*
June 15~18	5th International Conference on Environmental and Engineering Geophysics, Changsha, China
August 8-9	Waterborne High Resolution Geophysical Techniques And Applications, Rutland, UK
August 21	Deadline for submission of articles, advertisements, and contributions to the September issue of *FastTIMES*
September 3-5	18th European Meeting of Environmental and Engineering Geophysics of the Near Surface Geoscience Division of EAGE, Paris, France
September 17-19	Istanbul International Geophysical Conference, Istanbul, Turkey
September 23-26	First EAGE Workshop on Dead Sea Sinkholes: Causes, Effects and Solutions Hydrogeological Workshop on Dead Sea Sinkholes, Amman, Jordan
November 21	Deadline for submission of articles, advertisements, and contributions to the December issue of *FastTIMES*

President's Message: 25 Years of Excellence

Mark Dunscomb, President (mdunscomb@schnabel-eng.com)

Our annual conference, SAGEEP, will be held in Tucson, Arizona and will mark a silver anniversary. Twenty five years of steadfastly promoting near surface geophysics is something we all should be very proud of. It's in part due to the society's dedication to education. Learning has been a hallmark of EEGS since its inception and it's fundamental to our careers. It's also the application of that knowledge which keeps us excited about what we do. Geophysics provides a constant opportunity to learn new concepts and to expand what we know in new ways. This is what EEGS is all about.

Of course, SAGEEP is the most obvious center of information transfer for EEGS. There, you can find new technologies and approaches, other professionals who are willing to share their experiences, instrument designers explaining how they can help collect data in new ways and researchers who gladly share their newest findings.

However, SAGEEP is not our only source of education. Our publications are another obvious source of information. JEEG is the foremost journal on near-surface geophysics in the United States and provides an outlet for researchers to publish their work. FastTimes, EEGS' quarterly newsletter, is free to anyone who wants to download it from our web site and we get over 20,000 downloads per issue. EEGS also helps support the Early Career Award, given to professors that beginning their career in near surface geophysics, and subsidizes students who want to come to SAGEEP. Also, our joint cooperation committee with the SEG anticipates developing a program to reach out more effectively to students on behalf of the near surface community.

Check out the new EEGS website design that went on line this past year. If you haven't seen it or signed up for access, do so at www.eegs.org. The new platform provides us the ability to provide content in a secured environment and we are investigating ways to use it for education. For instance, one thought to consider is allowing those who attended SAGEEP to view presentations online that they missed at the conference. Another thought is to provide sponsored webinars or short courses via our website. The possibilities are only limited by our ideas and people to help enact them. If you are interested in helping manage or develop these ideas, contact Dr. Moe Momayez, the chair of our web committee.

I've found myself thinking about the 25th anniversary these past several months and wondering if those who organized the first SAGEEP in Chicago expected it would last this long, been as strong as it is, or would be still true to its roots. Did they anticipate the enormous changes in near surface geophysics over the past 25 years? What's ahead for the next 25 years? One thing is for sure, whatever we guess will probably not encapsulate it fully, but I can say confidently that education will remain a hallmark of the community. Here's to another 25 years!

EEGS Foundation makes great strides in its first years.

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

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

Allen, Micki
Arumugam, Devendran
Astin, Timothy
Baker, Gregory
Barkhouse, William
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Renew your EEGS Membership for 2012

Be sure to renew your EEGS membership for 2012! In addition to the more tangible member benefits (including the option of receiving a print or electronic 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 our web site to enable desired capabilities such as membership services, publication ordering, and search and delivery of SAGEEP papers. New this year is an opportunity to donate to the EEGS Foundation during the renewal process. Members can renew by mail, fax, or online at *www.eegs.org*.

Sponsorship Opportunities

There are always sponsorship opportunities available for government agencies, corporations, and individuals who wish to help support EEGS's activities. Specific opportunities include development and maintenance of an online system for accessing SAGEEP papers from the EEGS web site and support for the 2012 SAGEEP conference to be held in Tucson, Arizona. Contact Mark Dunscomb (*mdunscomb@schnabel-eng.com*) for more information.

EEGS Announces Changes in Membership

It's time to renew your membership in EEGS – we've added options and increased benefits!

EEGS members, if you have not already received a call to renew your membership, you will – soon! There are a couple of changes of which you should be aware before renewing or joining.

Benefits - EEGS has worked hard to increase benefits without passing along big increase in dues. As a member, you receive a Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) registration discount big enough to cover your dues. You also receive the Journal of Environmental and Engineering Geophysics (JEEG), the *FastTIMES* newsletter, and full access to the EEGS research collection, which includes online access to all back issues of JEEG, SAGEEP proceedings, and SEG extended abstracts. You get all of this for less than what many societies charge for their journals alone.

Dues Changes - EEGS has worked hard to hold the line against dues increases resulting from inflation and higher costs. Instead, EEGS leadership sought ways to offer yesterday's rates in today's tough economic climate. Therefore, you can continue your EEGS membership without any rate increase if you opt to receive the JEEG in its electronic format, rather than a printed, mailed copy. Of course, you can continue to receive the printed JEEG if you prefer. The new rate for this membership category is modestly higher reflecting the higher production and mailing costs. A most exciting addition to EEGS membership choices is the new discounted rate for members from countries in the developing world. A growing membership is essential to our society's future, so EEGS is urging those of you doing business in these countries to please encourage those you meet to take advantage of this discounted membership category, which includes full access to the EEGS research collection. And, EEGS is pleased to announce the formation of a Retired category in response to members' requests.

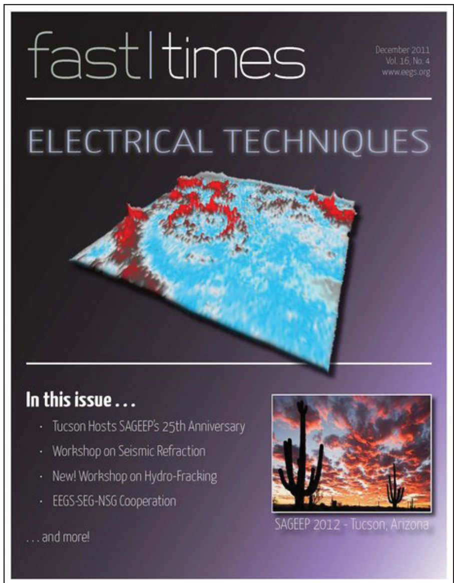
Descriptions of all the new membership options are outlined on EEGS' web site (www.eegs.org) in the membership section.

Renew Online - Last year, many of you took advantage of our new online membership renewal (or joining EEGS) option. It is quick and easy, taking only a few moments of your time. Online membership and renewal application form is available at www.eegs.org (click on Membership and then on Online Member Application / Renewal).

EEGS Foundation - EEGS launched a non-profit foundation (www.eegsfoundation.org) that we hope will enable our society to promote near-surface geophysics to other professionals, develop educational materials, fund more student activities, and meet the increasing demand for EEGS programs while lessening our dependence on membership dues. A call for donations (tax deductible*) to this charitable organization is now included with your renewal materials and can be found on the online Member Resources page of EEGS' web site (www.eegs.org/pdf_files/eegs_foundation.pdf).

Member get a Member - Finally, since the best way to keep dues low without sacrificing benefits is to increase membership, please make it your New Year's resolution to recruit at least one new EEGS member. If every current member recruited even one new member to EEGS, we could actually consider lowering dues next year!

*As always, seek professional advice when claiming deductions on your tax return.



From the FastTIMES Editorial Team

FastTIMES is distributed as an electronic document (pdf) to all EEGS members, sent by web link to several related professional societies, and is available to all for download from the EEGS web site at http://www.eegs.org/Publications/FASTTIMES/LatestIssue.aspx. The most recent issue (December 2011, cover image at left) has been downloaded more than 13,000 times as of March 2012, 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.

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

The JEEG Page

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.*

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Journal of Environmental & Engineering Geophysics

March 2012 Volume 17 Issue 1

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The Environmental and Engineering Geophysical Society

Journal of Environmental & Engineering Geophysics
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Editor's Scratch

Dr. Janet E. Simms, ***JEEG*** Editor-in-Chief
US Army Engineer R&D Ctr.
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
(601) 634-3493; 634-3453 fax
janet.e.simms@erdc.usace.army.mil

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

EAGE's Near Surface Geophysics Journal, February 2012

*As a courtesy to the European Association of Geoscientists and Engineers (EAGE) and the readers of **FastTIMES**, we reproduce the table of contents from the February issue of EAGE's **Near Surface Geophysics** journal.*

EAGE
EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

Near Surface Geophysics

Volume 10 · Number 1 · February 2012

Content

www.nearsurfacegeophysics.org

Success with Geophysics

FastTIMES *welcomes short articles on applications of geophysics to the near surface in many disciplines, including engineering and environmental problems, geology, soil science, hydrology, archaeology, and astronomy. In the articles that follow, the authors present examples of electrical sensing techniques to near surface investigations.*

Proximal Soil Sensing: Global Perspective

V.I. Adamchuk[1], B.A. Allred[2], R.A. Viscarra Rossel[3]

(1) Bioresource Engineering Department, McGill University, Ste-Anne-de-Bellvue, QC, Canada

(2) USDA/ARS Soil Drainage Research Unit, Columbus, OH, USA

(3) CSIRO Land and Water, Bruce E. Butler Laboratory, Canberra, ACT, Australia

As a result of a number of naturally occurring processes and cultural practices, the characteristics of soils demonstrate substantial spatial heterogeneity that affects current land use. From infrastructure development to agriculture, spatial variability in soils must be taken into account in order to optimize on-going practices. To better understand this variability, remote and proximal soil sensing techniques have been developed. Although there are similarities, the two approaches provide different technical capabilities to obtain georeferenced data on many soil parameters at different scales and times.

While remote sensing is based on airborne and satellite platforms, ***Proximal Soil Sensing*** (PSS) is a set of technologies developed to measure the physical, chemical and biological properties of soil when placing the sensor in contact with, or at a proximal distance (less than 2 m) to, the soil being characterized (Viscarra Rossel et al., 2011). Unlike benchtop equipment, PSS instruments allow for a relatively large number of measurements to be obtained rapidly and at a relatively low cost. Currently developed sensing systems may be categorized by the manner in which they operate. They may be static or mobile, invasive or non-invasive, active or passive, and direct or indirect (Figure 1).

According to the mode of operation, most PSS systems can be deployed stationary, when they are placed at a fixed position for a relatively short period of time, or on-the-go, when measurements are gathered while the instrument is in motion. Furthermore, some measurements may not require mechanical interaction between the sensor and the soil (non-invasive), while other measurements are based on physical propagation of the instrument through the soil (in-situ), or even mechanical extraction of a soil sample (ex-situ). On the other hand, passive sensors rely on an ambient source of energy to quantify certain physical phenomena, and active sensors include their own source of such energy. Finally, and what is most remarkable, is that in a few instances, measured values can be directly related to a given soil property, while the majority of PSS systems provide measurements that can be correlated to a given set of soil properties indirectly.

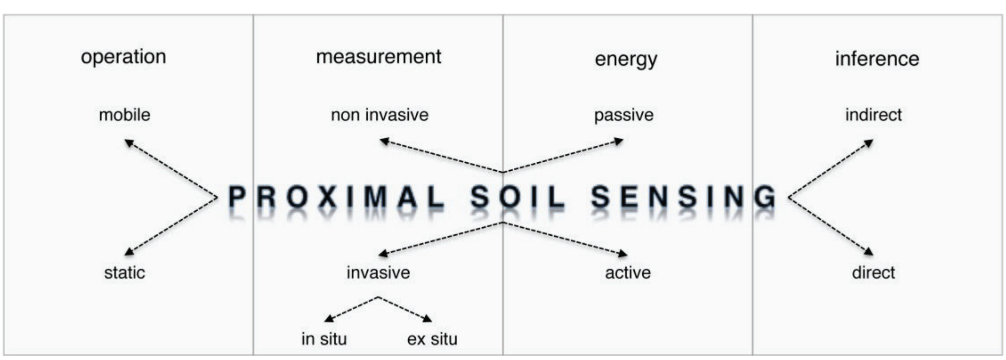

Figure 1. Classification of Proximal Soil Sensing Systems (Viscarra Rossel et al., 2011).

Hummel et al. (1996), Sudduth et al. (1997), Adamchuk et al. (2004), and Shibusawa (2006) reviewed different types of sensors that have been used, or are under development. Viscarra Rossel et al. (2011) provided a review of PSS using the electromagnetic spectrum as the organizing framework. From this review, it follows that a large number of PSS systems are based on measuring the soil's ability to reflect or emit energy in different parts of the electromagnetic spectrum, ranging from gamma-rays and X-rays, to ultraviolet, visible, infrared, and even radio-waves. In addition, most widespread sensor systems rely on the ability of soil particles to conduct and accumulate an electrical charge. Also, several PSS instruments depend on quantifying the mechanical interaction between the sensor and soil as well as ion-selective potentiometry.

In particular, gamma rays are in the high-frequency range (10^{20} to 10^{24} Hz) with quantum energies between 124 keV and 1 MeV. They include active and passive gamma-ray spectrometry, Inelastic Neutron Scattering (INS), Thermalized Neutron Methods (TNM), Neutron Probes (NP), and Cosmic Ray Neutrons (CRN). At lower frequencies (10^{17} to 10^{20} Hz) and quantum energies between 124 eV and 124 keV, X-ray instruments have been developed that could be classified as 'hard' (short wavelength, high energy) or 'soft' (long wavelength, low energy). X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) are examples of such tools.

Ultraviolet/visible/infrared measurement techniques provide a large array of alternatives. They are based on diffuse reflectance (or atomic emission) spectroscopy and offer soil measurements that are rapid, relatively inexpensive, safe, non-invasive and provide simultaneous measurements of multiple soil properties. The EM frequency range is from 10^{12} Hz (MIR) to 10^{15} Hz (UV). Optical techniques also include Laser Induced Breakdown Spectroscopy (LIBS).

The microwave region occurs in the EM spectrum at frequencies between 3×10^{9} and 3×10^{11} Hz with quantum energies between approximately 12.4 μeV and 12.4 meV. Although the research is limited, microwave PSS systems are typically based on soil emissivity or microwave attenuation changes under changing water content. On the other hand, radio waves cover the EM spectrum at frequencies less than 3×10^{9} Hz and energies less than 12.4 μeV. There are a large range of techniques used for PSS in this band that include: Time Domain Reflectometry (TDR), Frequency Domain Reflectometry (FDR), capacitance probes, Ground Penetrating Radar (GPR), Nuclear Magnetic Resonance (NMR), and, certainly, Electromagnetic Induction (EMI). Researchers in the area of agricultural geophysics have examined numerous applications of these techniques.

More direct, electrical resistivity methods also have become popular, while involving direct contact between sensor components and the soil (galvanic contact or capacitively coupled methods). Electrochemical methods are based on electrochemical sensors e.g. Ion Selective Electrodes (ISEs) and allow direct soil chemical measurements through a variety of techniques. Finally, mechanical techniques are based on the physical interaction between the sensor and soil, which include: soil strength sensors, penetrometers, acoustic, and pneumatic techniques.

Every soil-sensing technology has strengths and weaknesses and no single sensor can measure all soil properties. Table 1 indicates some of the most apparent direct and indirect relationships between soil attributes and PSS system measurements. In many instances, these relationships were found to be site-specific or stable over certain geographical regions.

Therefore, the selection of a complementary set of sensors to measure the required suite of soil properties has become the quest of different research projects around the world. Integrating multiple, proximal soil sensors in a single, multi-sensor platform can provide a number of operational benefits over single-sensor systems, such as: robust operational performance, increased confidence as independent measurements are made on the same soil, extended attribute coverage, and increased dimensionality of the measurement space (e.g., conceptually different sensors allow for an emphasis on different soil properties).

Table 1. Predictability of Main Soil Properties Using Different Soil Sensing Concepts (adapted from Viscarra Rossel et al., 2011)

Soil property[1]	Sensor type							
	Gamma-ray	X-ray	Optical	Microwave	Radio wave	Electrical	Electrochemical	Mechanistic
Chemical								
Total carbon	D	D	D					
Organic carbon	I		D					
Inorganic carbon	I		D					
Total nitrogen	D	D	D					
Nitrate-nitrogen			I		I	I	D	
Total Phosphorus	D	D	I					
Extractable phosphorus								
Total Potassium	D	D	D					
Extractable potassium			I				I	
Other major nutrients	D	D	D					
Micronutrients, elements	D	D	D					
Total Iron	D	D	D		I			
Iron oxides	I		D		I			
Heavy metals	D	D	I					
CEC	I		I			I		
Soil pH	I		I		D		D	
Buffering capacity and LR			I				I	
Salinity and sodicity					D	D	D	
Physical								
Color			D					
Water content	D		D	D	D	D		I
Soil matric potential	I					D		I
Particle size distribution	I		I		I	I		I
Clay minerals	I	D	D			I		I
Soil strength								D
Bulk density	I		I		D			I
Porosity								D
Rooting depth					I			D

[1] – soil properties directly (D) or indirectly (I) predictable using different types of proximal soil sensors

While sensor fusion and the integration of remote sensing and crop-based data have become the leading research trend, the nature of this type of exploration calls for an international and interdisciplinary approach. Therefore, an International Union of Soil Science workgroup on Proximal Soil Sensing (http://proximalsoilsensing.org) has emerged with two global workshops and a number of conference symposia held within the last four years. The goal of the group is to facilitate communication among soil scientists, engineers, geophysicists, agronomists and representatives of other disciplines to evolve and promote proximal soil sensing technology to improve our understanding of soil variability in space and time.

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Gamma and Electro Magnetics: A multi-sensor approach for the mapping of water related soil properties

E.H. Loonstra
The Soil Company, Leonard Springerlaan 9, 9727 KB Groningen, The Netherlands
loonstra@soilcompany.com

Abstract

For the mapping of subsoil water related soil properties a multi-sensor approach was chosen in order to obtain high resolution input for a decision support system. The gamma ray sensor the Mole was applied for top soil mapping, an EM38 for the mapping of soil profiles. Calibration of both sensor systems for the different soil layers went well in practice. Statistical analysis shows that both sensors provide independent data from top soil and subsoil. It is concluded that a multi-sensor approach is appropriate with soil conditions as described.

Introduction

In 2008 and 2009 two water related sensor projects were set up in the north-eastern part of the Netherlands. In these projects the local water board and land users worked together in setting up an integral decision support system (DSS) for water management in the area. The water levels are a constant issue for debate between the water board and farmers. Where the main concern of the farmers is the availability of water for their crops, the board has to take into account other issues, such as safety and wetness of nature. The aim of both projects was to bring the needs of both parties involved more in line. Two important objects of study were the appliance of real-time soil moisture probes and the use of high resolution digital soil information as input for the water models as applied by the board. The projects took place in an area of approximately 60.000 ha, mainly arable land for starch potato production. In this area 60 plots of 5 hectare each were chosen to be mapped by the soil sensor systems and water to be monitored by the probes. High resolution digital water related soil maps of the top soil and subsoil were required as input for the water models in the DSS. This was a novel approach, as the water board tends to focus on water in the substrata. The soil maps were used to pinpoint appropriate locations for the water probes. In this study 15 fields are selected for analysis.

Materials and Methods

The area lies south of the city Stadskanaal, with centre co-ordinates N 52.92, E 6.91. The soil type in this area can be characterised as humus sandy soils with a sandy top soil. It originates from a peat soil, but has been heavily cultivated since the 17th century. The result is that the top soil differs significantly from the subsoil in most cases, with parent material starting at 30 to 80 centimetres. Within the top soil the organic matter content can vary significantly over short distance. The gamma ray soil sensor the Mole was applied for the quantitative mapping of the top soil (Egmond et al, 2008) and the EM38 for the qualitative mapping of the subsoil soil profiles (Geonics). In a number of surveys both sensors were conducted in one run, both attached to the same vehicle as depicted below. In other cases the survey of the EM and gamma ray sensor was done in two separate runs. The sensors were moved with a speed of approximately 6 km/hr at tram lines of 15 meter. Data was logged every second, resulting in dense coverage of the fields. In addition, in all fields the compaction was mapped with a penetrometer in a 20 meter grid.

In each field 4 to 6 samples were taken from the top soil for calibration purposes of the gamma ray data. The soil properties organic matter, clay content (2 µm), loam content (50 µm) and grain size M50 were modeled by multi linear regression. This was done on a field scale or on a regional scale for similar soil types (Loonstra, 2008). The resulting soil maps were input for the mapping of continuous pedotransfer functions for water retention, field capacity and hydraulic saturated capacity (Wösten et al, 2001). For the calibration of the EM data, management zones were identified based on comparison of the collected EM38 and gamma ray data, and consequently soil profile samples were taken and described for each significant zone. The standard Dutch soil classification method (Stiboka) was applied for describing the soil profile characteristics. Examples of the soil maps are depicted below.

Figure 1. The gamma ray sensor the Mole in the lift of the tractor and the EM38 towed at the same time.

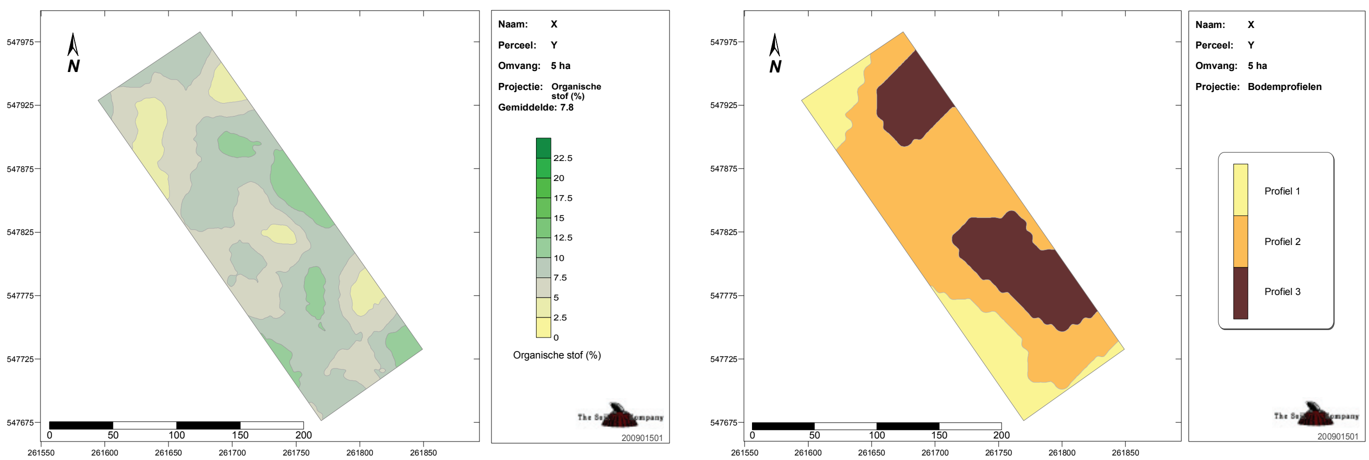

Figure 2. Organic matter content map of top soil and soil profile map of subsoil.

Results

The outcome of the soil samples of the 15 fields confirmed the expected variance of soil properties. The organic matter content is the property that differs greatly, also within fields, followed by variance in loam content. Grain size and clay content show little variation.

Table 1. Variance of top soil properties

	Organic matter	pH	clay	loam	Grain size
Minimum	3.7%	4.0	1.6%	6.5%	116 µm
Maximum	40.6%	5.6	8.0%	27.8%	144 µm
Average	12,2%	4.9	3.1%	12.8%	127 µm

The correlation of the top soil properties with the gamma ray nuclides can be qualified as good, with an R2 ranging between 0.7 and 0.9.

Table 2. Calibration models for top soil properties with radioactive nuclides

Soil property	Main nuclides	General model
Organic matter	^{137}Cs, ^{40}K	OM = a + b x Cs – c x K
pH	^{238}U	pH = a + b x U
Clay content	^{232}Th	Clay = a + b x Th
Loam content	^{232}Th, ^{238}U	Loam = a + b x (Th + U)

The calibration of EM data for soil profiles was done on a field scale. Again, 4 to 6 sample locations were identified, where soil profiles were described. In most cases it was possible to identify differences in soil type and layer thickness in line with the observed EM zones. However, as the final soil profile map is qualitative by nature the within-field boundaries remain arbitrary.

The suitability of the multi-sensor approach was analysed by comparison of the raw data of both sensors. The correlation between the radioactive elements and the EM38 data was examined for the 15 fields. No significant correlation was found between the output of both sensors for any of the fields. An overview of the outcome of the analysis is shown in the table below.

Table 3. Regression coefficient of Mole radioactive nuclides and EM38 data

R^2	^{40}K-EM	^{238}U-EM	^{232}Th-EM	^{137}Cs-EM	Total Counts-EM
Minimum	0.001	0.000	0.000	0.000	0.000
Maximum	0.158	0.230	0.169	0.163	0.314
Average	0.035	0.045	0.023	0.030	0.073

The final high resolution soil maps from both sensors were constructed with a 5m grid size. This meets the needs of the water models that are based on 20m grid data or larger. The level of detail of the soil maps was also suitable for the models. The presented classes were finer compared to the classes used in the water models.

Conclusion

This study shows that a multi-sensor approach can be useful in mapping soil properties for the complete subsoil. Under the described circumstances where top soil differs in composition from the subsoil, gamma ray and EM sensors will provide differentiated sets of data that can be calibrated individually for the purpose of soil mapping. Calibration of gamma ray nuclides can be performed on a field for chemical properties and on a regional scale for physical soil properties from the same soil type. The calibration of EM data was conducted on a field scale, although it is believed that a regional approach could have been applicable as well. The high resolution maps from both sensors have sufficient detail to serve as input for the water models in the DSS.

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Proximal sensing of soil organic matter using the Veris® OpticMapper™

Eric D. Lund
Veris Technologies, Inc. Salina KS USA
lunde@veristech.com

Abstract

Soil organic matter (OM) affects productivity and input usage in most crop production systems. Veris Technologies recently introduced a proximal optical sensor which measures soil reflectance in two wavelengths, and allows calibrations of the sensor with lab-measured OM. Used in conjunction with ancillary proximal sensors, including Veris soil electrical conductivity (EC) modules, the OpticMapper generates maps which provide additional details compared to government soil surveys and EC maps. Results from multi-field studies in several States show that OpticMapper readings correlate well with laboratory-measured OM, even in fields containing relatively low OM.

Introduction

Variations in soil properties can be detected, even with the human eye, based on differences in light reflectance. Darker soils contain higher levels of moisture or organic matter than light-colored soils. While this can be detected visually, light sensors in the visible and near infrared (Vis-NIR), can quantify the reflectance characteristics and provide the data for calibrating soil properties. Soil reflectance has been studied extensively since the 1970's and is widely reported in the scientific literature as an effective means for approximating soil organic matter (Sudduth et al., 1993). Organic matter is an important factor in crop growth, as it affects soil moisture infiltration and retention, soil tilth, rooting depth, soil-applied herbicide activity, nitrogen release, and other aspects of nutrient cycling (Bauer & Black, 1994). A precise map of organic matter would provide growers with important information as they seek to vary nitrogen, seed population, herbicides, and other inputs.

Veris Technologies began development of soil optical devices in 2002 and has patents pending on commercialized Vis-NIR spectrophotometer systems for mapping soil (Christy et al., 2003). The level of technology inherent in a spectrophotometer may be required in soil research, and where carbon measurements require an extremely high level of precision, but are not practical for grower and consultant use due to expense and complexity. Veris Technologies has leveraged its expertise from the higher-end systems in developing a two wavelength device, the OpticMapper, which has been commercially available since late 2010. The objective of this study was to evaluate the performance of the OpticMapper™ and soil EC sensing based on: 1) optical sensor repeatability, 2) correlation with lab-analyzed OM, and 3) utility of optical sensor versus EC-only measurements.

Materials and Methods

Soil optical and electrical conductivity (EC) data were collected with an implement designed and commercialized for the purpose of mapping with multiple soil sensors (Figure 1). The implement contains six coulter electrodes for EC measurements, and a specially-configured row unit for optical measurements. The optical module is mounted between two disks which operate at a slight angle, forming a V-shaped slot in the soil. A depth-gauging side wheel for each disk controls sensing depth. The row unit has a parallel linkage to follow ground undulations and adjustable down-force to match soil conditions. The optical module contains a light source and detector, collecting measurements in the red and near-infrared wavelengths through a sapphire window. The wear-plate with window is pressed against the bottom of the slot and the consistent pressure provides a self-cleaning function. Measurements were collected approximately 4 cm below the soil surface. The complete electronics package includes signal conditioning, A/D conversion, data logging and a GPS to geo-reference all data. Data were collected at a 1 hz rate on 15-20 m transects with typical field speed of 10-15 km/hr. Approximately 150-200 EC and optical data points per/ha were collected.

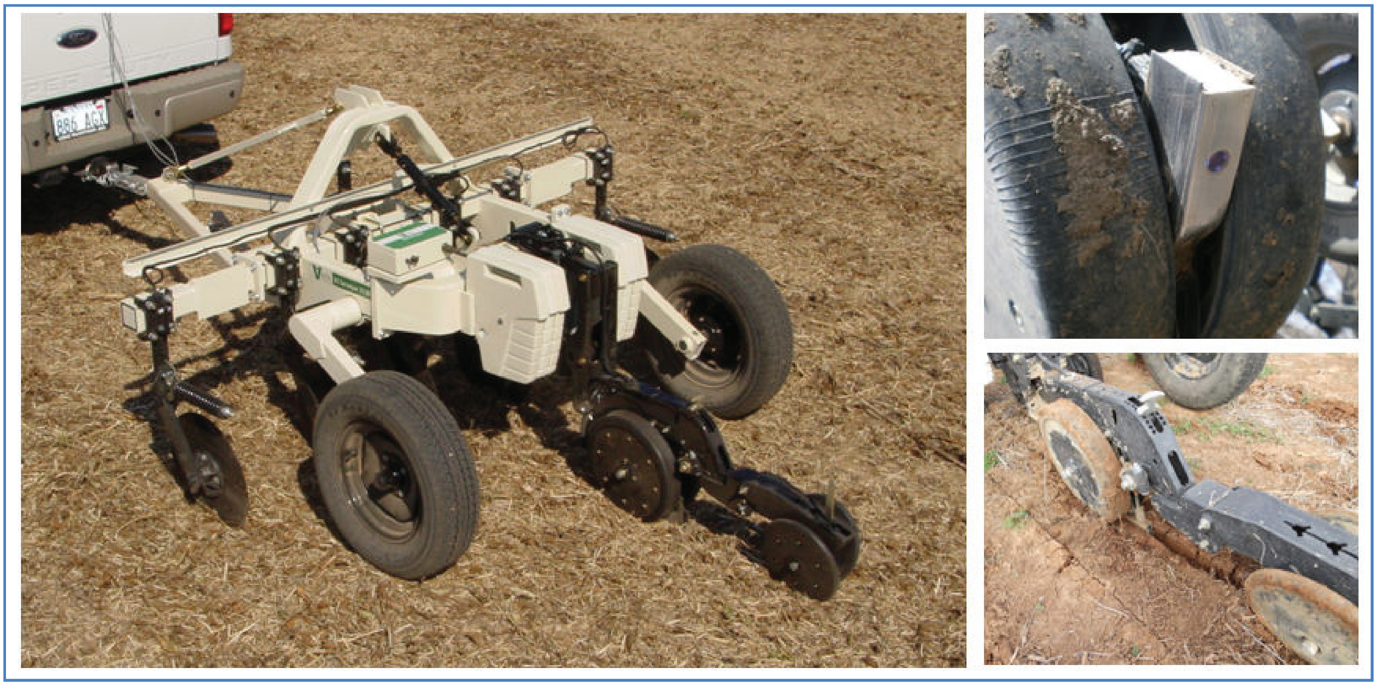

Figure 1. Veris OpticMapper with Soil EC and Optical Sensors.

The project covered more than 570 ha on 20 fields in 7 U.S. states, providing a wide range of soil types, conditions, and organic matter levels. From these fields,195 geo-referenced soil samples were analyzed for organic matter. A combination of wet digestion and dry combustion methods were used. These samples were a composite of a minimum of six 0-15 cm deep cores collected within a 10 m radius. The sensor data was queried to select values within a 5 m radius of the sample location centroid. Multi-variate regression (MVR) techniques were applied to the data set using optical, EC, and topography components. This process generated estimates of organic matter, and a leave-one-out cross-validation was used to select the optimal sensor combination.

Results

Sensor repeatability was evaluated by mapping fields at different time intervals, where soil moisture and tillage conditions had changed from previous mapping. Results showed that while absolute reflectance changed with soil conditions, the relative values and zone delineation were highly repeatable (Figure 2).

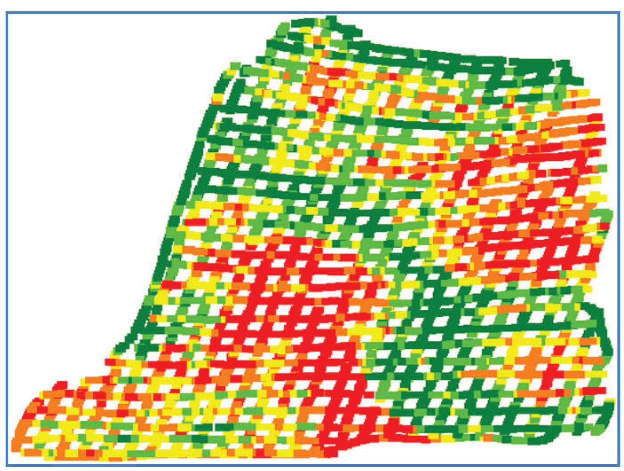

Figure 2. Raw sensor data from field mapped N-S on August 28, 2010 and E-W on September 7, 2010.

Results from cross-validation showed strong correlation between sensor-estimated and laboratory analyzed organic matter (Table 1). The root-mean-square errors (RMSE) were less than 0.35% OM in all but Ohio, where the standard deviation of OM was the highest at 1.57. The ratio of prediction to deviation (RPD) was greater than 1.5 on all sites, with all but two sites above 2. Sensor-estimated OM maps exhibit strong spatial structure and visual correlation to lab-analyzed soil OM (Figure 3).

Table 1. Organic matter lab analyses and relationships with sensor-estimated OM

State	N	ha	# of flds	Std. dev.	Ave. OM %	OM % Range	R^2	RMSE	RPD
Kansas	24	132	4	0.54	2.3	1.6-3.5	0.93	0.14	3.86
Missouri	50	89	3	0.55	2.4	1.0-3.5	0.71	0.30	1.83
Iowa	41	65	2	0.51	4.3	3.4-5.5	0.57	0.33	1.55
Illinois	42	172	5	1.06	2.5	.4-5.1	0.95	0.23	4.61
Michigan	11	61	1	0.64	3.0	1.7-4.5	0.91	0.27	3.41
Ohio	13	85	3	1.57	2.8	1.3-6.9	0.85	0.59	2.66
Alabama	14	95	2	0.72	1.7	.9-3.5	0.79	0.32	2.25

One of the many properties that EC maps have been found to relate to indirectly is organic matter (Jaynes et al., 1994). This is likely due in part to spatial autocorrelation between soil texture and OM; for example, very sandy soils typically have low OM levels. To help determine whether optical sensing offers any additional utility to EC mapping, the relationship between EC and optical measurements was examined. The best correlation found was between EC shallow and the red wavelength, however that relationship was generally not strong, with an average of 0.33 R^2. Only three of the 20 fields showed a relationship greater than 0.60 R^2.

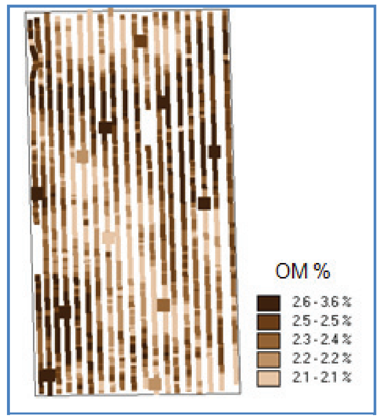

Figure 3. Laboratory analyzed soil sample results overlaid on Veris OpticMapper map.

Conclusion

OpticMapper sensor measurements were reproducible and highly correlated with lab-analyzed OM. On most fields, optical and EC measurements were independent. The optical sensor represents an important addition to the proximal sensing options for improved soil mapping.

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2D Resistivity Imaging Investigation of Long Point, Katy-Hockley, Tomball and Pearland Faults, Houston, Texas

Mustafa Saribudak
Environmental Geophysics Associates, Austin, TX, USA
ega@pdq.net

Abstract

Active growth faults cutting the land surface in the Gulf Coast area may represent a serious geo-hazard. Although the average movement of these faults is only a few inches per decade, the potential exists for structural damage to highways, industrial buildings, residential houses and railroads that cross these features. We have conducted 2D resistivity imaging surveys at two sites over two known locations of Long Point fault (Moorehead at Westview, and NW section of east Beltway 8 and I-10 intersections) in the southwest part of Houston, Texas; Katy-Hockley and Tomball faults are located in the northwest part, and the Pearland fault in the southeast part of the Houston area. Results of 2D resistivity surveys on four faults in the Houston area have identified resistivity anomalies that can be used to locate the faults, determine the extent of near-surface deformation, and provide geological information.

Introduction

The Houston area has a very active shallow fault system as evidenced by active surface movement and measurable localized subsidence (Verbeek, R., E. & Clanton S. U., 1981). Evidence of faulting is visible from structural damage such as fractures and/or displacement. Faults are listric growth faults with dominantly dip-slip (normal) displacement to the south, although antithetic faults are present that dip to the north. In the near surface, fault dip is usually 60 to 75 degrees. Some active faults are clearly evident in surface damage such as scarps across lots, fields and streets. Vertical offset is commonly the most visible aspect of fault movement. Because the near-surface dip of the faults is usually 60 to 75 degrees, horizontal extension equivalent to one-half to one-fourth of vertical component of movement takes place. This movement tends to pull the subsurface material apart (Elsbury et al., 1980). Today, active faults are the source of heavy damage to pavements, utilities, homes businesses, and other man-made structures in the Gulf Coast region. In the Houston area alone (Harris County), there are more than 300 active or potentially active faults totaling over 300 miles in length. These active faults are not discrete ruptures. Rather, they are zones of intensely sheared ground tens of meters wide (Clanton, S. U., and Verbeek, R.E., 1981).

One of the most significant faults of the Houston area is the Long Point Fault, which runs from near US 290, west-southwest through the Beltway/I-10 Interchange to near Eldridge Parkway in west Houston, a distance of about 11 miles (Figure 1). It is a typical Gulf Coast growth fault that moves (creeps) slowly about 1/4 to 1 inch per year crossing through many neighborhoods and deforming many residential and commercial buildings. The fault plane dips about 70-degrees from the horizontal toward the coast (southeast).

This paper presents the resistivity imaging data along with observations made on the surface deformation of the Long Point Fault at Moorehead and Westview, and Beltway 8 and I-10 intersections, Katy-Hockley and Tomball Faults in the northwestern part of the Harris County, and Pearland Fault in the southeast of metropolitan Houston area (Figure 1).

Resistivity Technique

Resistivity imaging is a surface geophysical technique, which is used to build define the electrical properties of the subsurface by passing an electrical current along electrodes and measuring the associated voltages. This technique has been used widely in determining plumes, karst features, such as voids, and subsurface structures, such as faults and fractures (Dahlin, 1996, Seaton and Dean, 2004, Saribudak, 2010). For this study, we used the Advanced Geoscience Inc's (AGI) Super R1 Sting/Swift resistivity meter with dipole-dipole resistivity technique, which is sensitive to horizontal changes in the subsurface, and provides a 2-D electrical image of the near-surface geology..

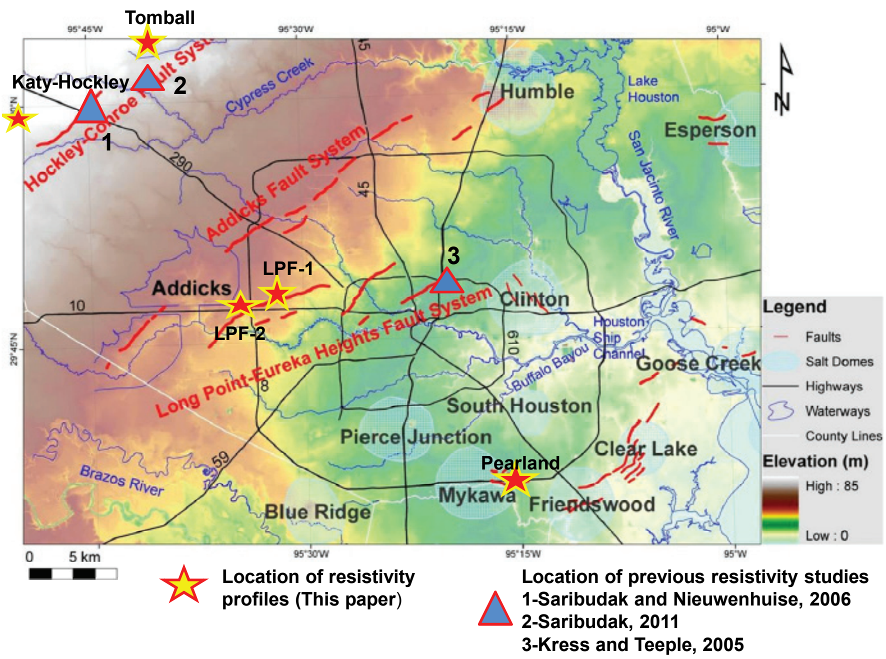

Figure 1.
Lidar elevation map of Houston showing NE-SW trending faults and resistivity survey locations (revised from Engelkemeir and Khan, 2008). LPF-1 and LPF-2 abbreviations indicate Long Point fault locations.

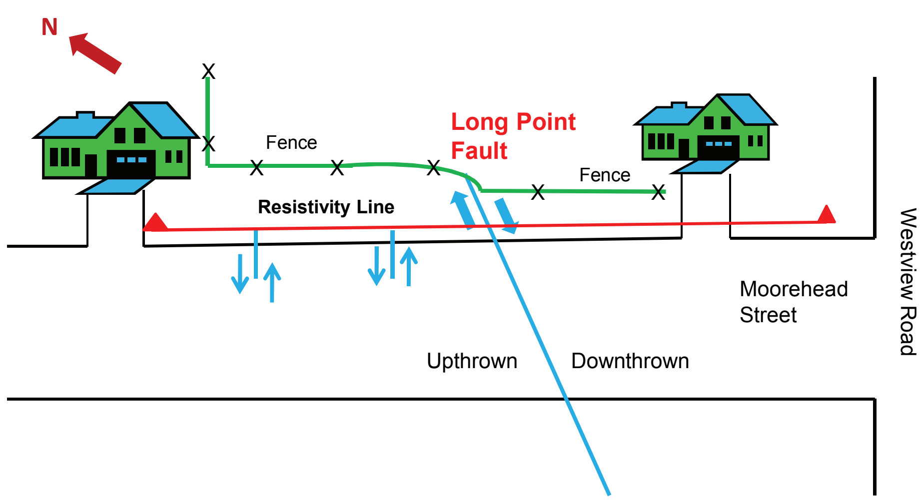

Figure 2.
Schematic map of Long Point fault at Moorehead Street. Note the presence of two small faults in the upthrown side of the fault, and the deformation on the fence line. Resistivity line is shown with a red line.

Field Data Collection and Processing

We collected resistivity data over Long Point fault at two locations: along Moorehead street near Westview Road, and at a location near Beltway 8 and I-10 intersection (see Figure 1). During the field survey at the first location, we sketched the cracks and patched pavement locations and/or fences deformed by the fault (Figures

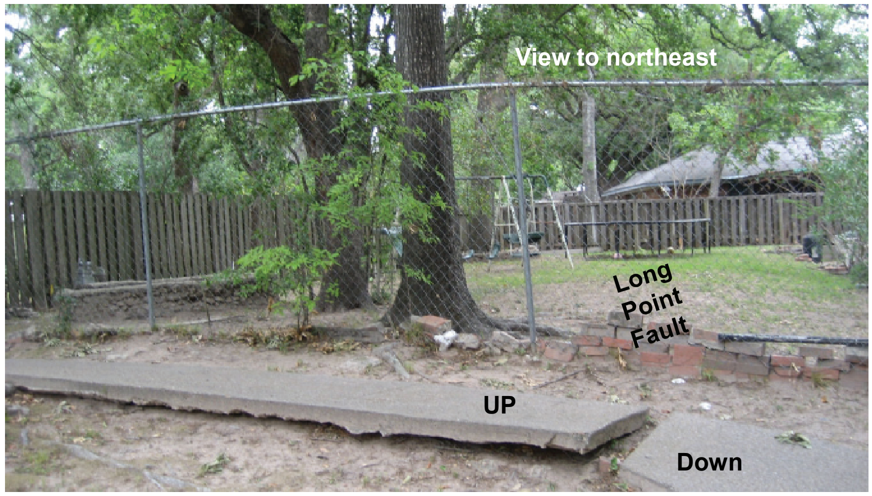

Figure 3.
Long Point fault scarp across Moorehead Street. Note the fault related deformation on the concrete path for pedestrians.

2). At the Moorehead Street location a discrete fault scarp deforms the road, curbs and sidewalks (Figure 3). Figure 4a shows the approximate location of the Beltway 8 and I-10 study area, where the fault clearly deforms the fence, respectively (Figure 4b and Figure 5).

We conducted resistivity surveys over Katy-Hockley fault in the year 2005. For the Tomball fault, we were hired in the year of 2006, and for the Pearland fault in 2007.

We inverted the resistivity data into geo-electric sections using AGI's Earth Imager software. The resistivity values obtained in this study varied between 2 and 2000 Ω-m. Resistivity values, in general, between 1 and 10 Ω-m corresponds to clay; resistivity values between 10 and 25 Ω-m represent clayey sand, silty clay, sandy clay; and 25 Ω-m and above fine sand deposits (Kress and Teeple, 2005). Following color scales for 2D resistivity sections were used: high resistivity (low conductivity) is displayed in red color whereas low resistivity (high conductivity) is represented by blue color. The background resistivity values are shown with the green color.

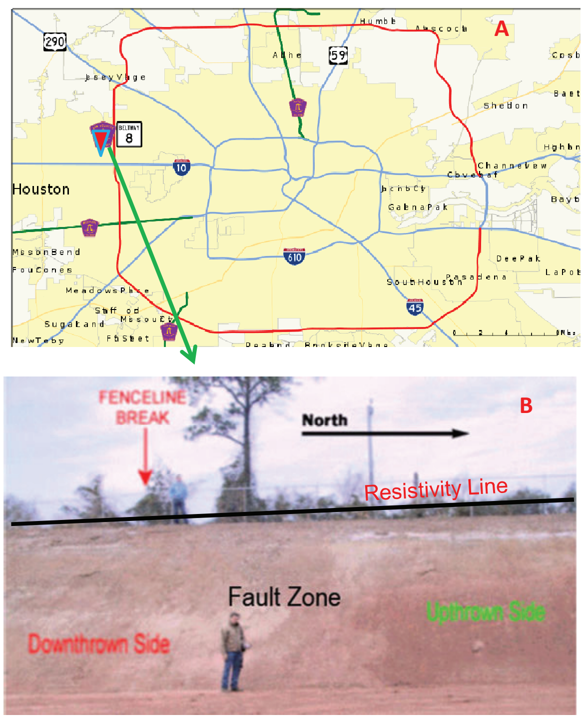

Figure 4.
a) Location of Beltway 8 and I-10 resistivity profile; b) a photo taking in 2006 shows the west wall of the excavated pit for the development of the water detention pond (picture is revised from Britt, P. 2006). Note the location of the resistivity line.

Definition of Resistivity Anomaly

Definition of a geophysical anomaly is defined as a deviation from uniformity in physical properties (Sheriff, 1994; p.10). The resistivity method is used to detect changes in the electrical properties of the subsurface. The electrical properties of soils and rocks are determined by water content, mineralogical clay content, salt content, porosity, and the presence of metallic materials. Thus the resistivity anomaly can also be defined as any changes in the soil properties mentioned above. In general, in the absence of tectonic activity, the soil layers should present horizontal layers in the Gulf Coast region. In the case of a growth fault, the different soil layers are juxtaposed within the fault zone .We attempted to model such a growth fault. Figure 6A indicates the synthetic model showing the silt, sand and clay layers displaced along the fault with a 30 feet vertical offset. Figure 6B and C show the inverted resistivity and synthetic apparent resistivity section, respectively. Figure 6B displays the fault movement and the thickening the soil layers on the downthrown side.

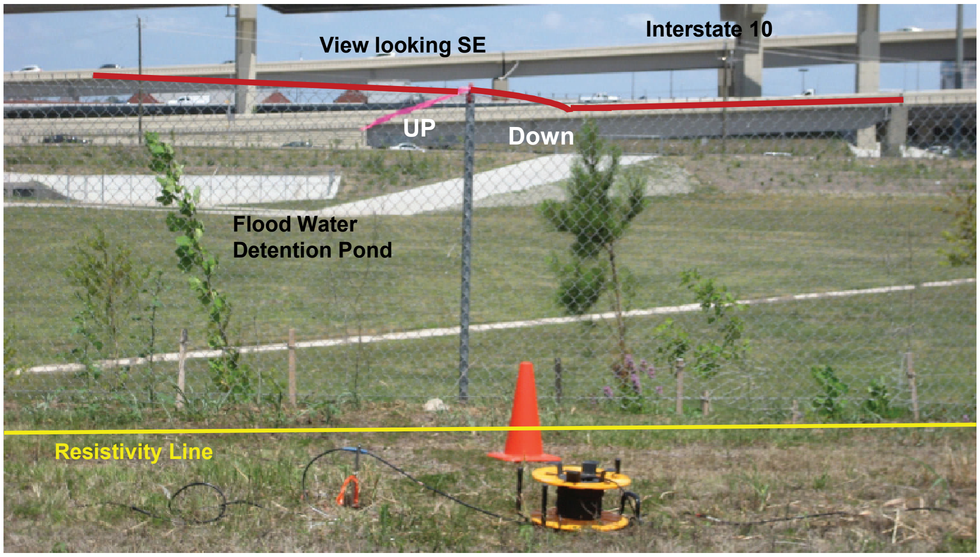

Figure 5.
A picture taken in 2011 shows the resistivity line with respect to the west wall of the detention pond, which is fenced, and the fence break-line indicates the fault location.

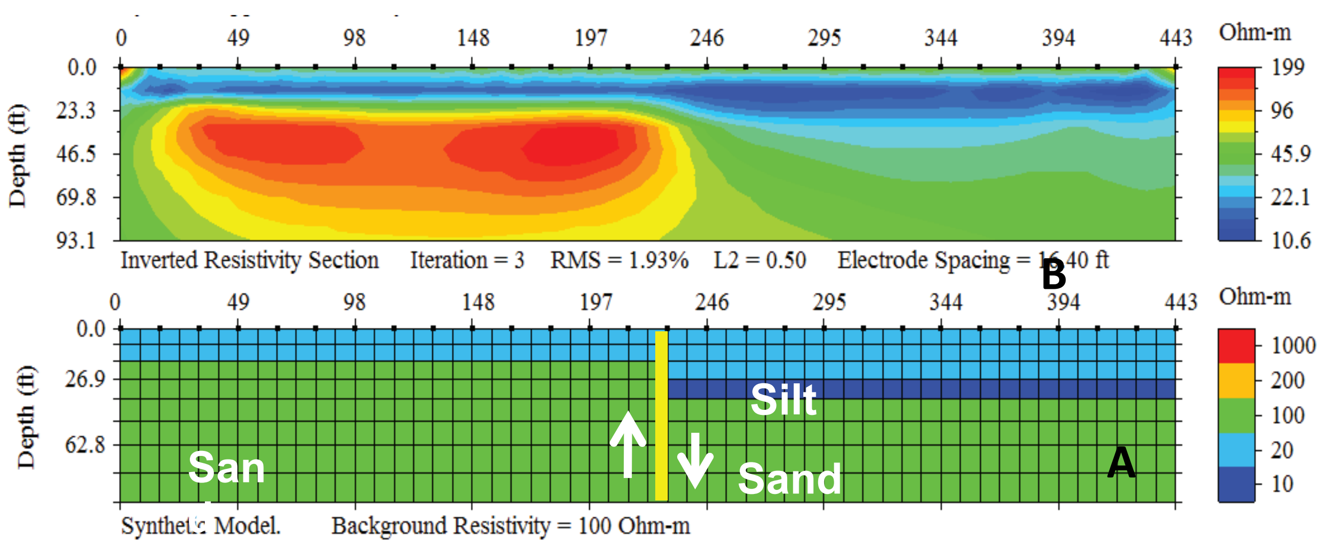

Figure 6. Sections showing (A) a synthetic fault model, and (B) resistivity inversion result of fault model within sand and clayey soils.

Resistivity Imaging of Long Point Fault

1) At Moorehead Street and Westview Road

The resistivity data collected along the Moorehead Street is shown in Figure 7. A fence-line break and the driveway of a nearby house are given for references. The fault juxtaposes low resistivity soil layers (clay as displayed by the blue) against moderately resistive units (sand as displayed by green color). The Long Point fault location observed at the site is superimposed on the resistivity imaging data, which shows south-dipping clay layers on the south part of the fault trace. The northwest part of this anomaly is limited by a high resistivity layer shown by the red color.

2) At East Beltway 8 and Interstate I-10

Resistivity data collected over the fault show south-dipping clay layers in the south part of the Long Point fault (Figure 8), which juxtaposes low resistivity soil (clay as displayed by the blue color) against moderately resistive units (sand as displayed by the green color).

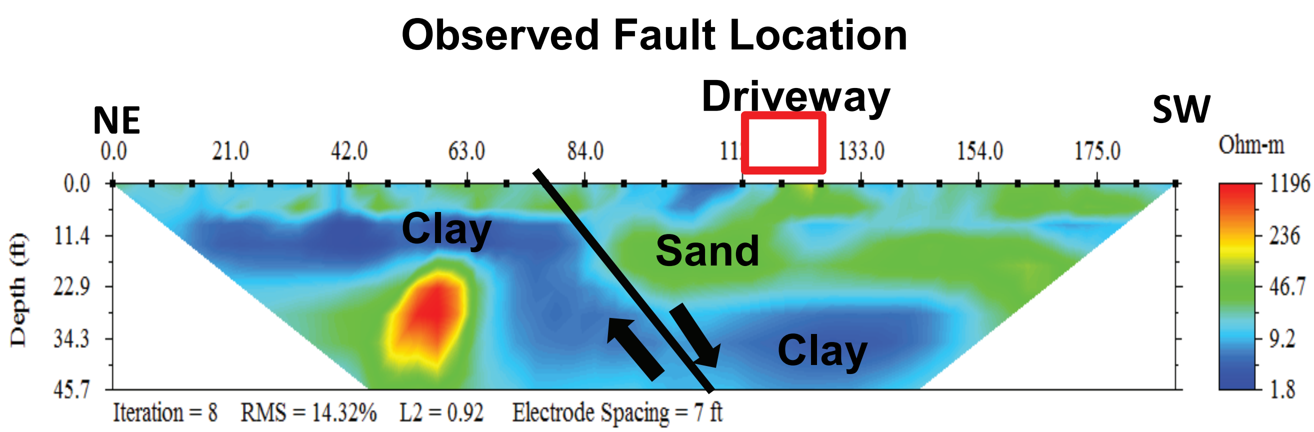

Figure 7. Resistivity imaging data taken along Moorehead Street across the Long Point fault.

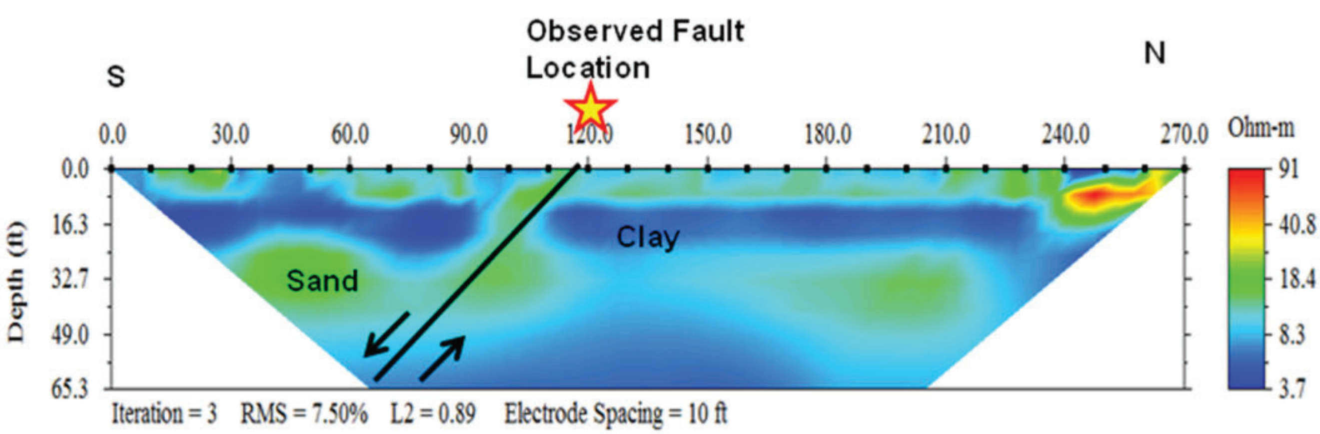

Figure 8. Resistivity imaging across Long Point fault. Note the south-dipping clay layers in the downthrown side.

Katy-Hockley Fault

The E-W striking and south-dipping Katy-Hockley fault crosses Katy-Hockley Road 2235 feet to the north of the intersection of Jack and Katy-Hockley Roads. There was no deformation observed on the road because the road was built newly prior to the resistivity survey. The resistivity data collected across the fault (Figure 9) indicate a thickening of the clay and sand units on the downthrown side of this growth fault.

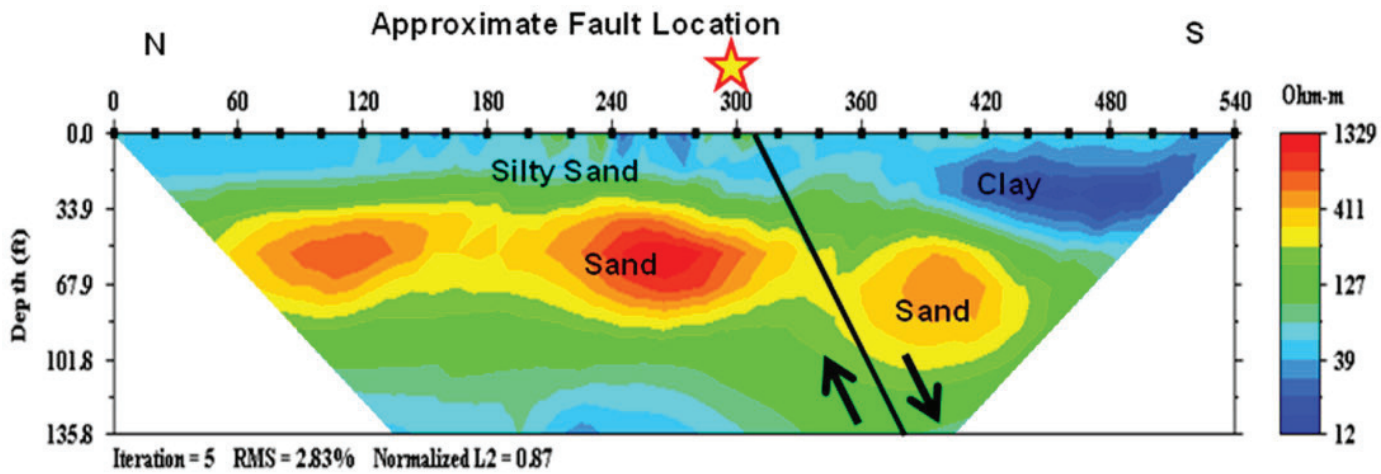

Figure 9. Resistivity imaging data taken across the Katy-Hockley fault. Note the south-dipping sand layers and thickening clay layers in the downthrown side.

Tomball Fault

The Tomball fault is one of the major regional faults of the Houston area, and is located in Tomball City. The fault strikes in the east-west and crosses SH 249. Further east, it runs through Beckendorf Middle School, which is located between Sandy Lane and Quinn Road (Figure 10). The fault deformed and damaged the west entrance of the school extensively. Because of the destruction of the property, the school was closed permanently in 2009.

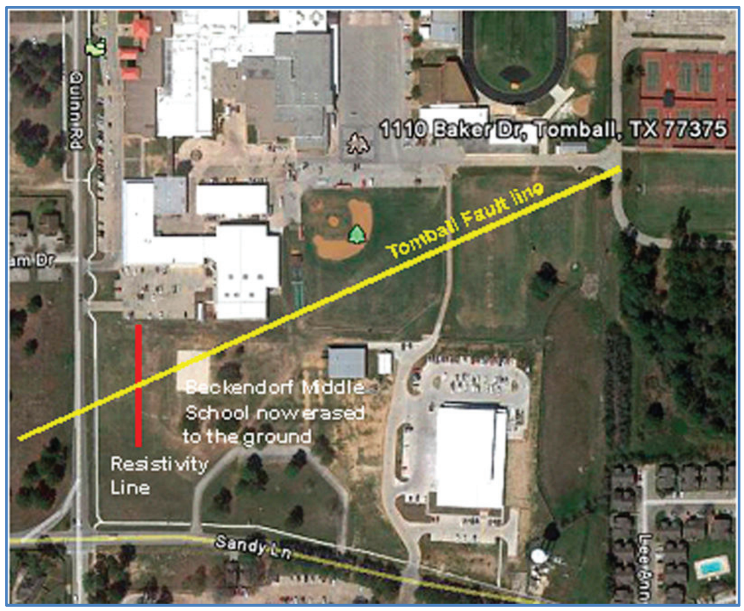

Figure 10. Beckondorf Middle School site map showing the Tomball fault line and location of the resistivity profile.

A line of resistivity data (Figure 11) was collected across the fault in the western part of the school area. The resistivity data is shown in Figure 11, which also shows the sketches of the school and deformation zone schematically. Available borehole data from the site indicates caliche. The resistivity data indicates a significant deformation

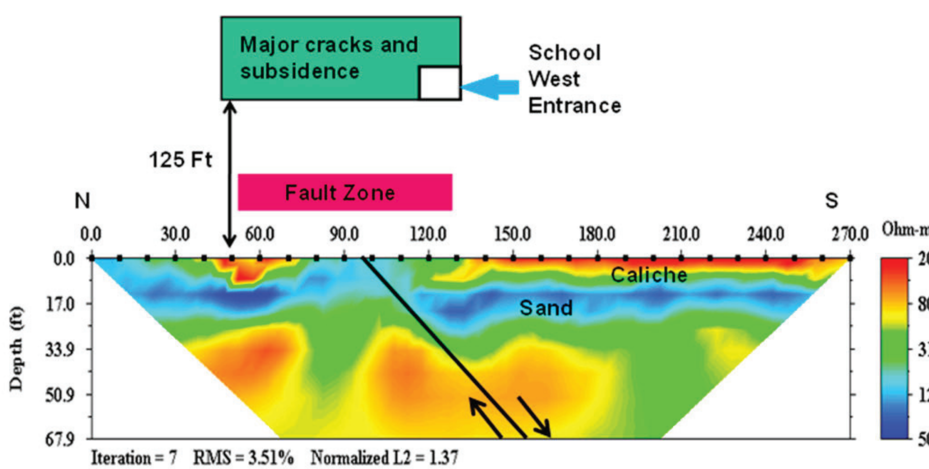

Figure 11. Resistivity imaging data taken across the Tomball fault at the western side of the Beckendorf Middle School. Note the significant deformation within the fault zone defined by the resistivity data, and thickening sand layers in the downthrown side of the fault.

zone between stations 50 and 130 feet, in which sand layers are displaced upwards and downwards. Away from the fault zone, the sand layers are horizontal. We observed major cracks on the wall of the school corresponding to the resistivity anomalies.

Pearland Fault

A blind test of the technique was conducted in the winter of 2007; we were asked us to perform a resistivity survey over the Pearland fault. Two resistivity profiles 10 feet apart were run across the fault for data redundancy (Figure 12).

Figure 12. A picture, looking SW, showing the location of resistivity line 1 across Pearland fault.

Results of both profiles are shown in Figure 13. Data from the 4 boreholes were used to project the surface location of the fault (at about 260 ft) along the profiles; the fault dips about 70° to the SW. Both resistivity profiles indicate a low resistivity area between stations at 220 and 320 feet. The resistivity for this anomaly varies between 5 and 10 Ω-m, which is indicative of clay. This low resistivity zone was interpreted to be a fault zone anomaly prior to any knowledge on the exact location of the fault. Note the approximate correlation of the fault location based on the borehole data (station 260 feet) and the resistivity data (between stations 220 and 320 feet).

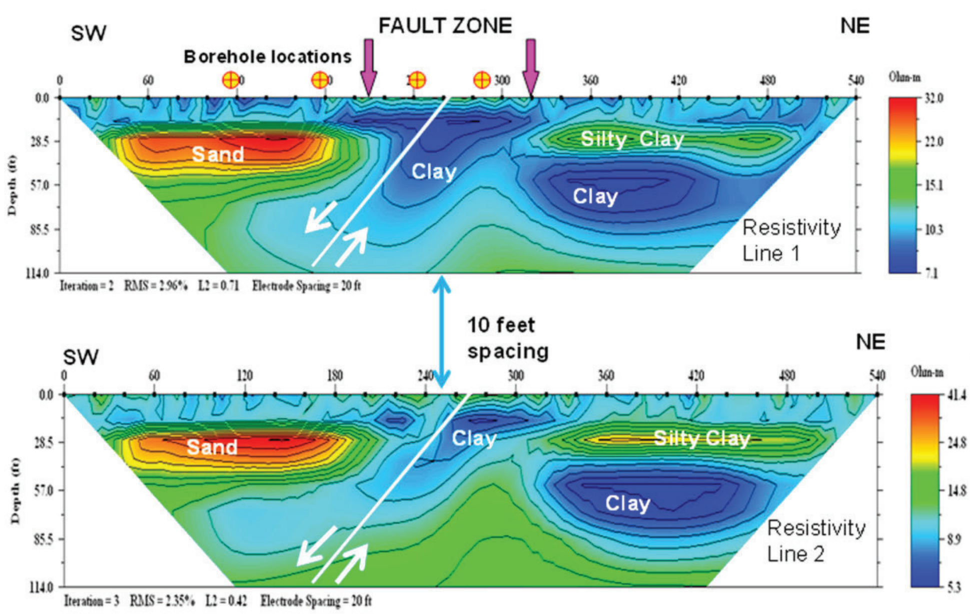

Figure 13.
Two resistivity imaging data sets taken across the Pearland fault. The fault location was not known prior to the resistivity surveys. Location of the fault is based on the four borehole data, and is projected onto the resistivity data.

Discussion

Three of these faults discussed in this paper (Long Point, Tomball and Katy-Hockley) are well known in terms of their locations and their extent. Resistivity anomalies across these faults appear to manifest themselves as south-dipping clay and/or sand layers, and significantly deformed sand and/or clay layers. It is important to point out that these anomalies are only restricted where the resistivity profiles cross the faults. Away from the faults, the resistivity data indicate, more and less, horizontal strata without any significant deformation.

The resistivity data in the Pearland area was obtained without knowing the exact location of the fault. We interpreted the abrupt termination of horizontal continuous sand and silty sand layers and the south-dipping clay layers between them along the two separate resistivity sections as anomalous and related to the location of the Pearland fault.

Previous resistivity results of by Saribudak and van Nieuwenhuise (2006), and Saribudak (2011) indicated similar anomalies across the Willow Creek and Hockley faults, respectively. In a similar study, Kress and Teeple (2005) obtained resistivity profiles coupled with borehole data across the Pecore fault in Houston (Figure 1). Their results (Figure 14) indicate discontinuous sand pockets and normally-displaced clay layers across the fault.

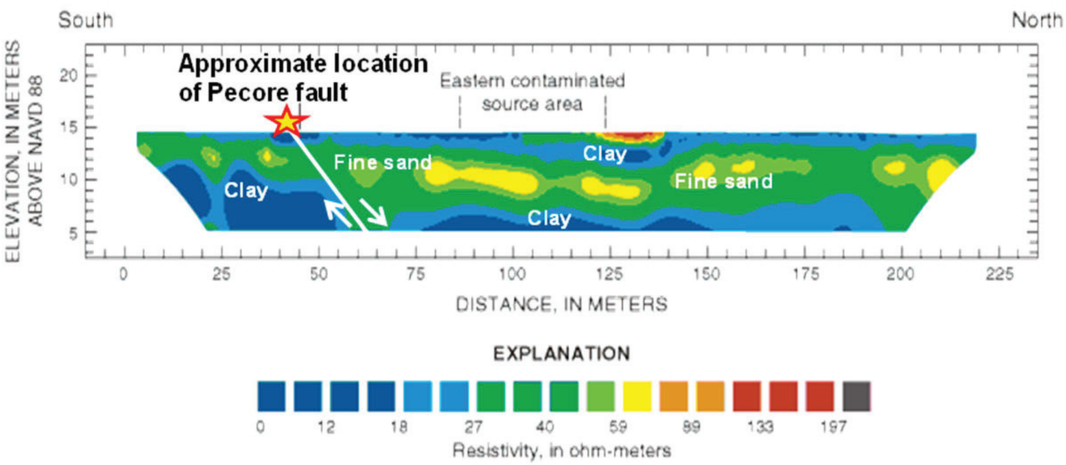

Figure 14. Resistivity profile showing the resistivity data across the Pecore fault (modified from Kress and Teeple, 2005).

In conclusion, data acquired across the known growth faults in the Houston area indicate a variety of anomalies associated with the faulting. These and previously published results indicate that the resistivity technique offer a viable method for detecting and mapping growth faults in the Houston area.

Acknowledgement

I am thankful to Bill Rizer and Dave Kress for their instructive and critical editing of the manuscript.

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Special Issue of JEEG: Time-Domain Electromagnetics

CALL FOR PAPERS

The Journal of Environmental and Engineering Geophysics (JEEG) announces a Call for Papers for a special issue on Time Domain Electromagnetics. This issue is scheduled for publication in March 2014.

The special issue editor is Antonio Menghini, Aarhus Geophysics, Denmark. Sponsorship of this issue is still open.

The main themes will focused on:

- New developments in equipment
- Data acquisition, modeling, and inversion
- Case histories, including:
    - hydrogeology (fresh-water detection, seawater encroachment)
    - engineering (sinkholes, slope stability, rock fracturing)
    - environment (leachate and pollutants detection, waste disposal, UXO detection, permafrost study)
    - exploration (oil and mining)
- Airborne Time Domain EM

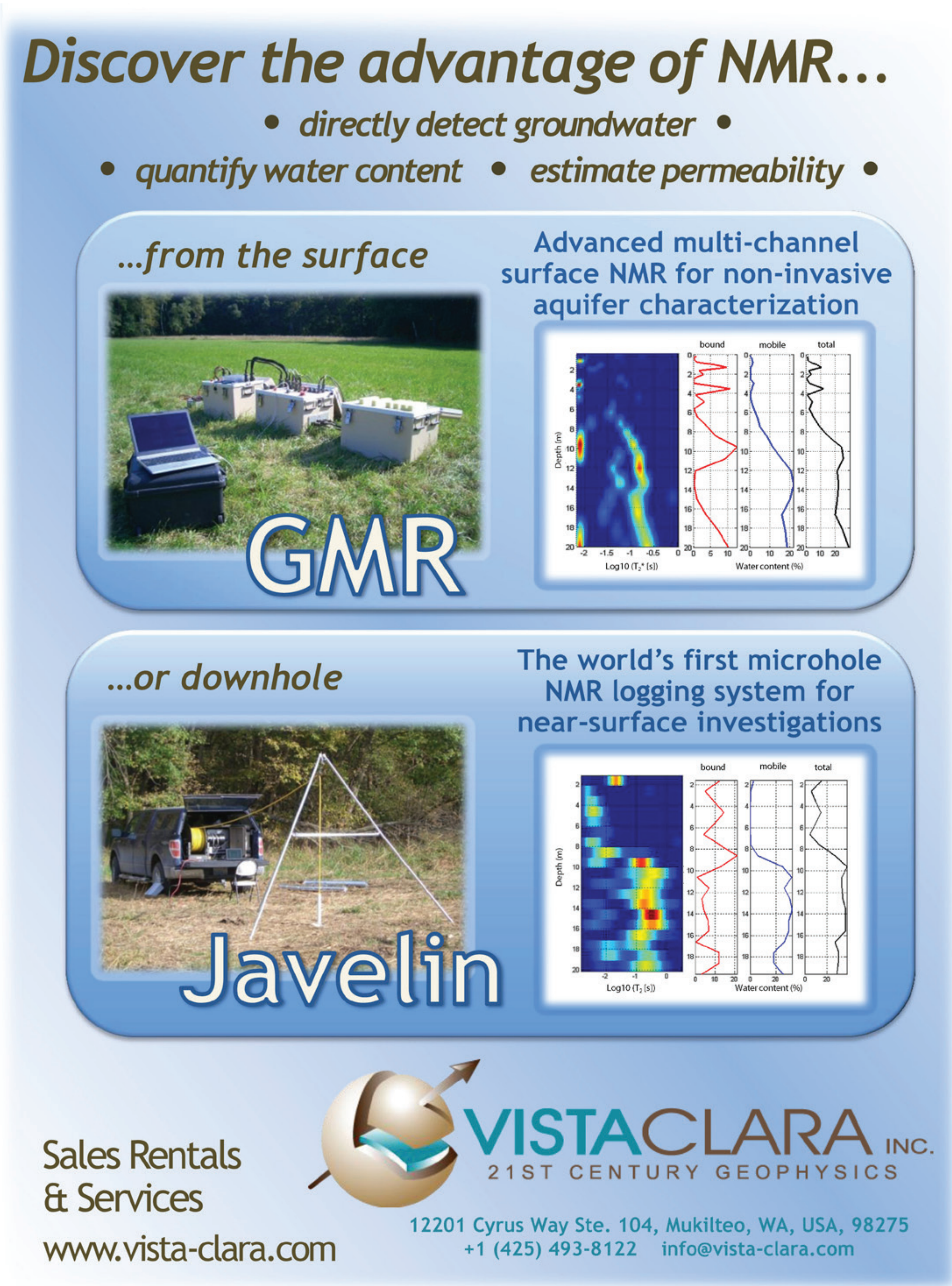
International contributions are encouraged. The special issue will accommodate eight papers, but all accepted papers will be considered for publication in other JEEG issues.

Papers may be submitted through the JEEG submission site, http://jeeg.allentrack.net. Indicate in the cover letter that the paper is for consideration in the TDEM special issue. The deadline for submissions is February 28th, 2013.

Questions may be directed to:

Special Issue Editor—Antonio Menghini, am@aarhusgeo.com

JEEG Editor—Janet Simms, Janet.E.Simms@usace.army.mil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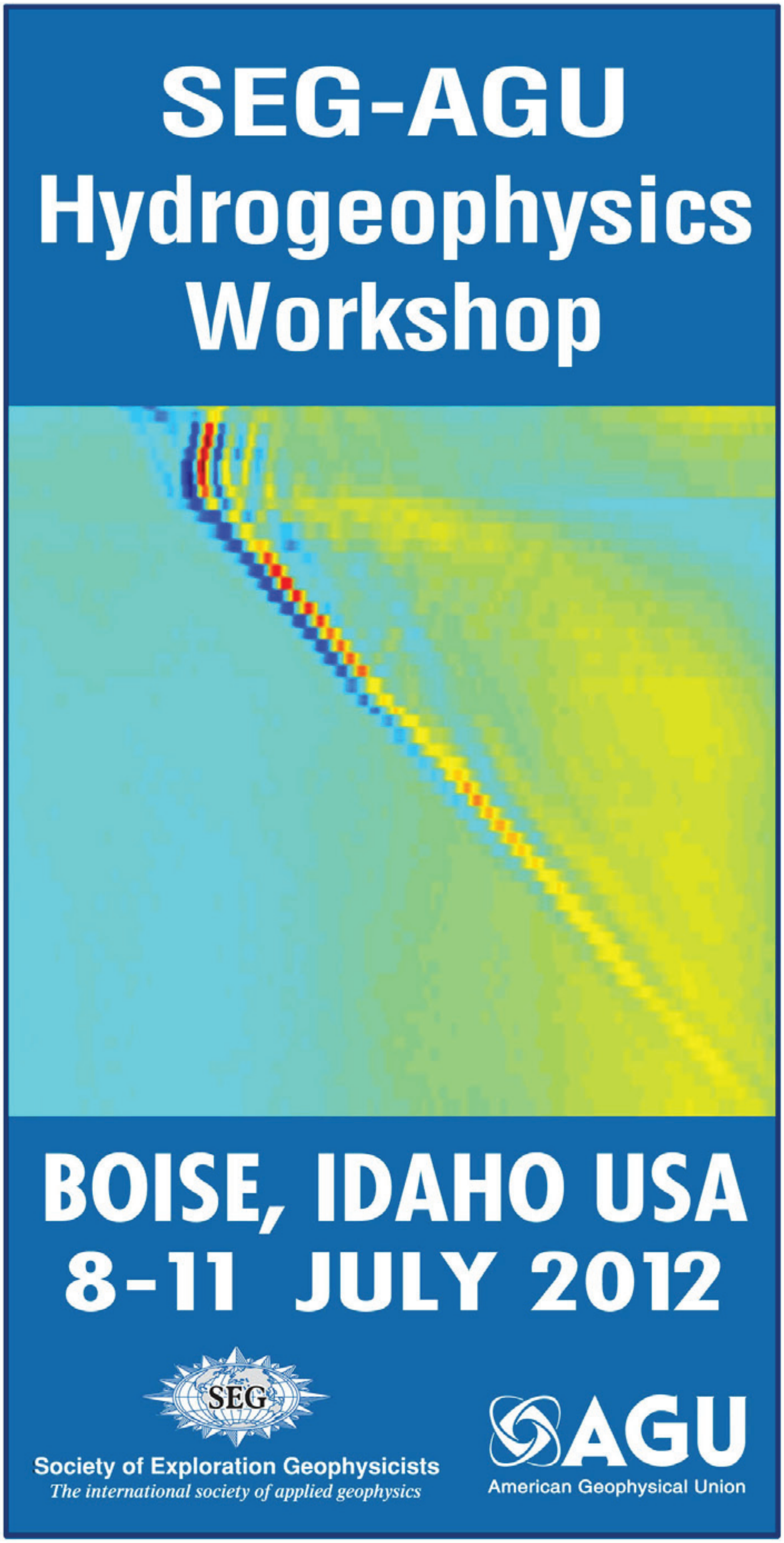
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Fostering International Collaborations in Geophysics

September 19 - 21, 2012
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Dear Colleagues;

We are very pleased to announce that the Korean Society of Earth and Exploration Geophysicists (KSEG) is organizing an "International Symposium on Geophysics for Discovery and Exploration" to be held at the International Convention Center (ICC) of Jeju Island, Korea on September 19 - 21, 2012.

Through sponsorship of this International Symposium, the KSEG intends to foster international collaborations in pure and applied geophysics between our members and our colleagues in other geophysical societies around the world.

For additional details and a preliminary program of the symposium, please visit our website: http://2012symp.seg.or.kr/.

Abstract submission: April 1 through June 30, 2012.
On-line registration deadline: August 15 (Wednesday), 2012.
The correspondent author should pre-register before July 31 (Tuesday), 2012.

We are looking forward to your participation.

Convener:

Dr. Mutaek Lim
Vice President of Korean Society of Earth and Exploration Geophysicists
phone: +82-42-868-3157, e-mail: limmt@kigam.re.kr

Coordinators:

Dr. In-ky Cho (Program Committee) : +82-33-250-8585, choik@kangwon.ac.kr
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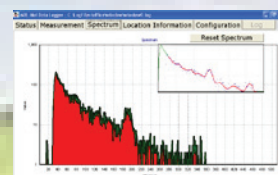

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- ✓ Data Logging software for gamma ray sensors in combination with any GPS, including RTK.
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- ✓ Tab based menu, easy access to all functions.
- ✓ Wizard based menus for startup procedure.
- ✓ Automatic data control functions for GPS en gamma ray data.
- ✓ Direct view of logged data, suitable for locating sample spots and logging sample data.
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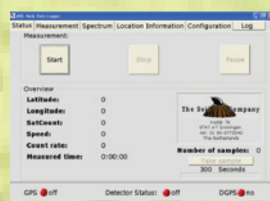

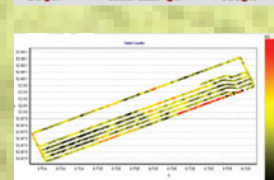

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		JEEG 4/1 – March
		JEEG 4/2 - June
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		JEEG 5/4 - December

Qt.	Year	Issue
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		JEEG 6/4 - December
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	2009	
		JEEG 14/1 - March
		JEEG 14/2 - Available June
		JEEG 14/3 - Available September
		JEEG 14/4 - Available December

SUBTOTAL—JEEG ISSUES ORDERED	

SUBTOTAL - SAGEEP PROCEEDINGS ORDERED	
SUBTOTAL - SHORT COURSE / MISCELLANEOUS ITEMS ORDERED	
SUBTOTAL - JEEG ISSUES ORDERED	
CITY SALES TAX (If order will be delivered in the City of Denver—add an additional 3.5%)	
STATE SALES TAX (If order will be delivered in Colorado—add an additional 3.7%)	
SHIPPING & HANDLING (US—$10; Canada/Mexico—$20; All other countries: $45)	
GRAND TOTAL:	

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

Payment Information:

☐ Check #: ______________________________ (Payable to EEGS)

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

☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover

Environmental and Engineering Geophysical Society

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

2012 Merchandise Order Form

ALL ORDERS ARE PREPAY

Sold To:

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

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

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

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

Merchandise Order Information:

ITEM DESCRIPTION	QTY	T-SHIRT COLOR WHITE/GRAY	MEMBER RATE	NON-MEMBER RATE	TOTAL
EEGS Mug			$10	$10	Sold Out
T-shirt (Medium)			$10	$10	Sold Out
T-shirt (Large)			$10	$10	Sold Out
T-shirt (X-Large)			$10	$10	
T-shirt (XX-Large)			$10	$10	Sold Out
EEGS Lapel Pin			$3	$3	
SUBTOTAL – MERCHANDISE ORDERED:					

TOTAL ORDER:

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

Payment Information:

☐ Check #: ______________ (Payable to EEGS)

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

☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover

Card Number: ______________ Cardholder Name (Print): ______________

Exp. Date: ______________ Signature: ______________

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

THANK YOU FOR YOUR ORDER!

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

EEGS/Forms/Merchandise Order Form/2010 Prices and details on this form are as accurate as possible, but are subject to change without notice.