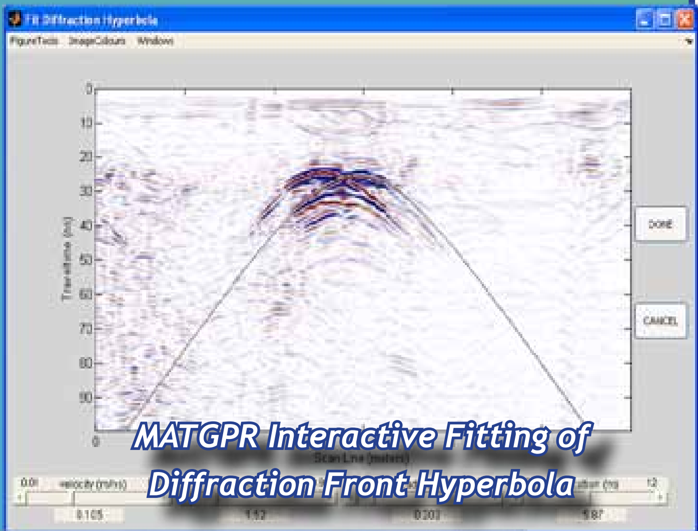
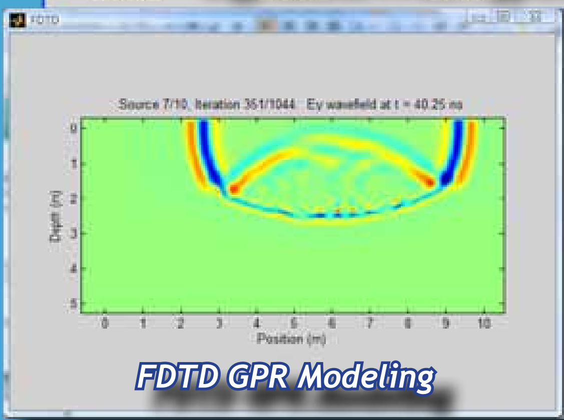
FastTIMES

April 2010
Volume 15, Number 1
www.eegs.org

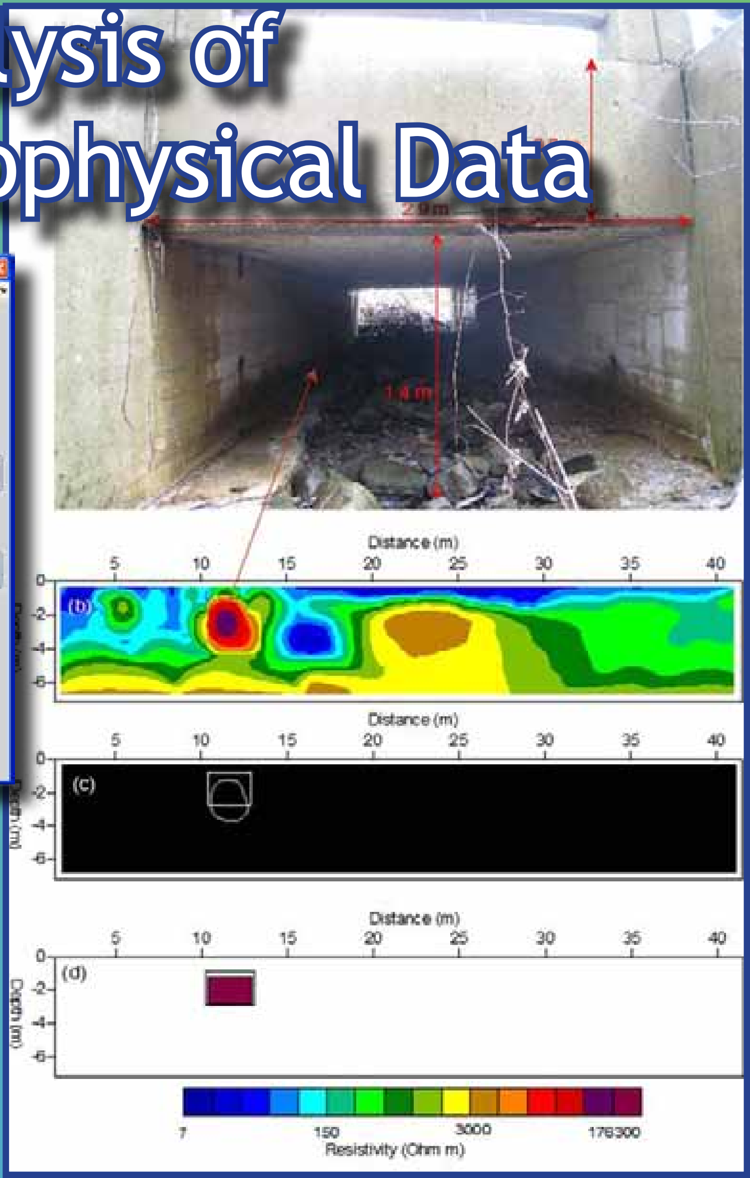
Software for Analysis of Near-Surface Geophysical Data



MATGPR Interactive Fitting of Diffraction Front Hyperbola



FDTD GPR Modeling



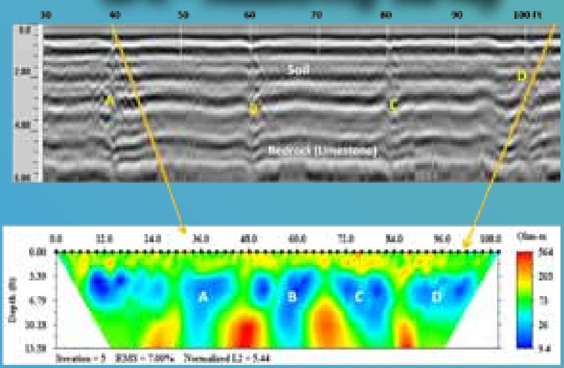
Neural Network Target Reconstruction

Also in this issue . . .

- New Products
- State-of-the-Art in Multi-Dimensional Electromagnetics
- Conference on Sinkholes & Karst
- Follow FastTIMES on Twitter

. . . and more!

GPR - Resistivity Survey



Park Seismic
Geotechnical Seismic Investigation

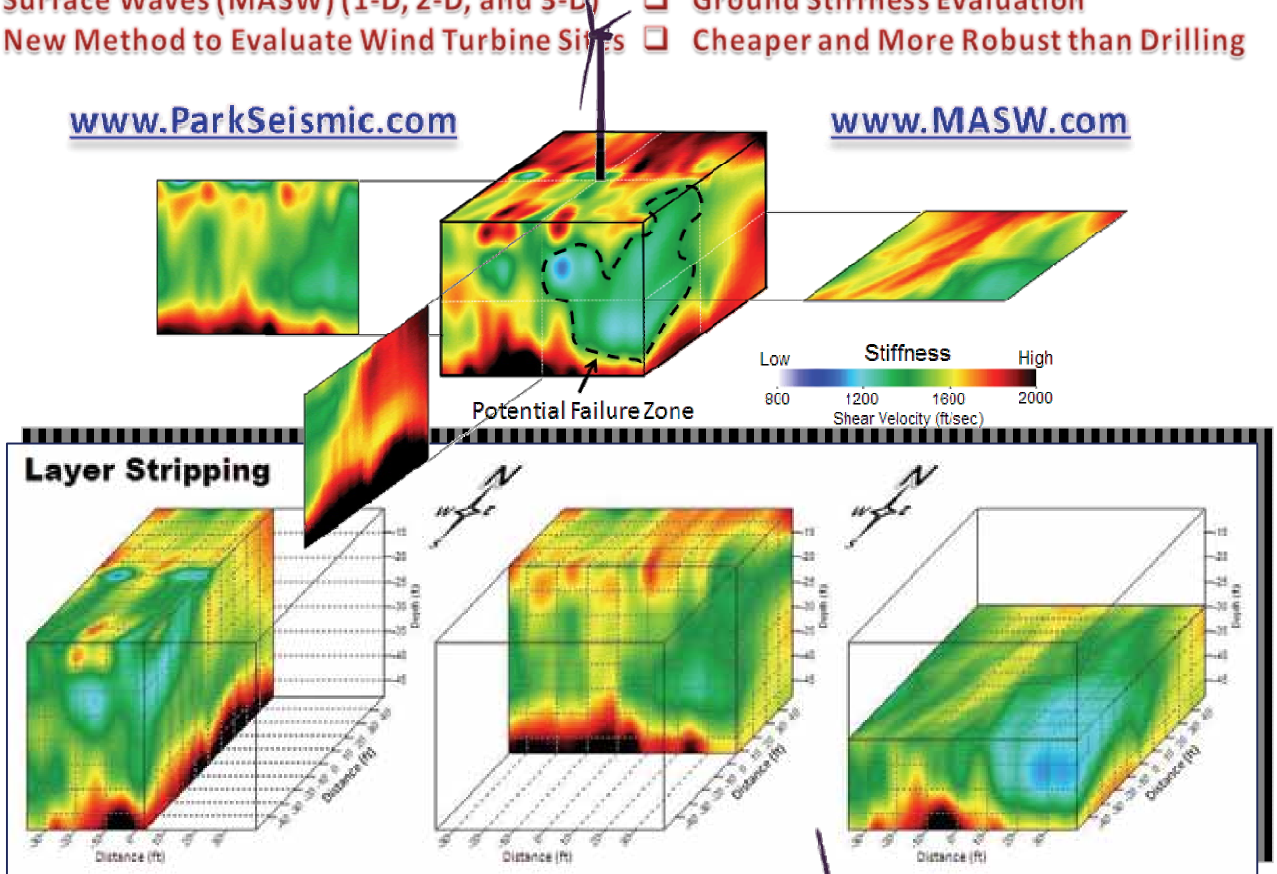
Wind-Turbine Site Seismic (MASW) Survey

Now Available

Data Analysis Services for Local Engineering Companies

- Specialized in Multichannel Analysis of Surface Waves (MASW) (1-D, 2-D, and 3-D)
- New Method to Evaluate Wind Turbine Sites
- Fast and Efficient
- Ground Stiffness Evaluation
- Cheaper and More Robust than Drilling

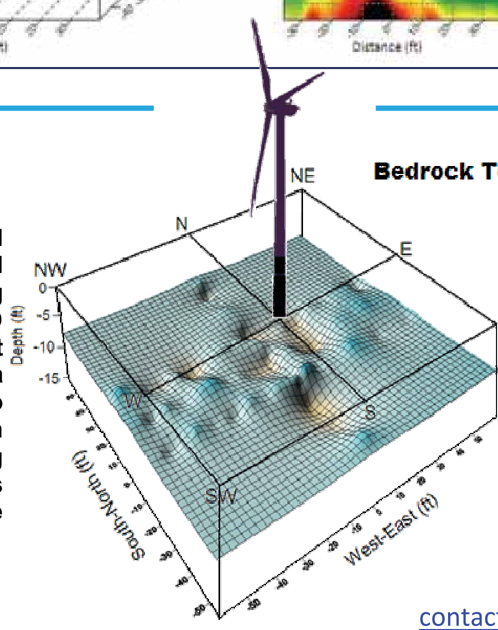
www.ParkSeismic.com www.MASW.com



Services Park Seismic Provides

Park Seismic provides a complete field survey and reporting service for seismic investigation of wind turbine sites in a flexible and prompt manner, ranging from the most basic 1-D analysis to a complete 3-D analysis depending on the site conditions and budget availability. Field surveys may be performed by a separate local engineering company according to instructions Park Seismic will provide and then subsequent data processing, interpretation and reporting will be performed at Park Seismic. Multiple-site surveys can take place in much a faster and more cost-effective manner than single-site surveys.

For more information, please contact Dr. Choon B. Park (choon@parkseismic.com, phone: 347-860-1223), or visit http://www.parkseismic.com/WindTurbine.html.



Park Seismic LLC
Shelton, CT 06484
Tel: 347-860-1223
Fax: 203-513-2056
contact@parkseismic.com
www.parkseismic.com

On the Cover

This issue features software developed for the analysis of near-surface geophysical data. **Upper right:** Advanced target recognition and interpretation using neural networks. **Upper left & center:** Screenshots of MATGPR, an open source software for advanced analysis of GPR signals. **Lower right:** GPR and Resistivity survey of thermal lines in limestone..

What We Want From You

The ***FastTIMES*** editorial team welcomes contributions of any subject touching upon geophysics. The suggested topic for the upcoming issue is civil infrastructure health monitoring and diagnosis. ***FastTIMES*** also accepts 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 May 31, 2010 to ensure inclusion in the next issue.

Advertisers

Click on the entries to see the ad

Contents

Click on the entries to see 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 for more information.

Board of Directors

President
Jonathan Nyquist, Philadelphia, PA
nyq@temple.edu

President, Elect
John Stowell,Denver, CO
john.stowell@mountsopris.com

Vice President, SAGEEP
Charles Stoyer, Golden, CO
charles@interpex.com

Vice President Elect, SAGEEP
Douglas Groom, San Jose, CA
doug@mail.geometrics.com

Vice President, Committees
Bruce Smith, Denver, CO
bsmith@usgs.gov

Vice President Elect, Committees
John Dunbar, Waco, TX
john_dunbar@baylor.edu

Past President
Barbara Luke, Las Vegas, NV
barbara.luke@unlv.edu

At-Large Board Members

Gregory S. Baker, Knoxville, TN
gbaker@tennessee.edu

Melvin Best, Victoria, BC
best@islandnet.com

Fred Boadu, Durham, NC
boadu@duke.edu

Soheil Nazarian, El Paso, TX
nazarian@utep.edu

Michael H. Powers, Denver, CO
mhpowers@usgs.gov

Dale Werkema, Las Vegas, NV
werkema.d@epa.gov

Business Office

1720 South Bellaire, Suite 110, Denver, Colorado 80222-4303; (303) 531-7517; 820-3844 fax; staff@eegs.org

Executive Director
Kathie A. Barstnar
staff@eegs.org

Managing Director
Jackie Jacoby
staff@eegs.org

EEGS Contributors

International Board Liaison
Micki Allen, Markham, ON
mickiallen@marac.com

General Chair, SAGEEP 2010
Victor Labson, Denver, CO
vlabson@usgs.gov

Technical Chair, SAGEEP 2010
James Lococo, Denver, CO
jim.lococo@mountsopris.com

Editor, JEEG
Janet Simms, Vicksburg, MS
janet.e.simms@erdc.usace.army.mil

FastTIMES Submissions

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

Editor in Chief
Moe Momayez
moe.momayez@arizona.edu
(520) 626-5977

Associate Editor
Jeffrey G. Paine
jeff.paine@beg.utexas.edu
(512) 471-1260

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

Jackie Jacoby
staff@eegs.org
(303) 531-7517

FastTIMES is published electronically four times a year. Please send articles to any member of the editorial team by May 31, 2010. Advertisements are due to Jackie Jacoby by May 21, 2010.

Unless otherwise noted, all material copyright 2010, Environmental and Engineering Geophysical Society. All rights reserved.

Meet us again, for the first time.

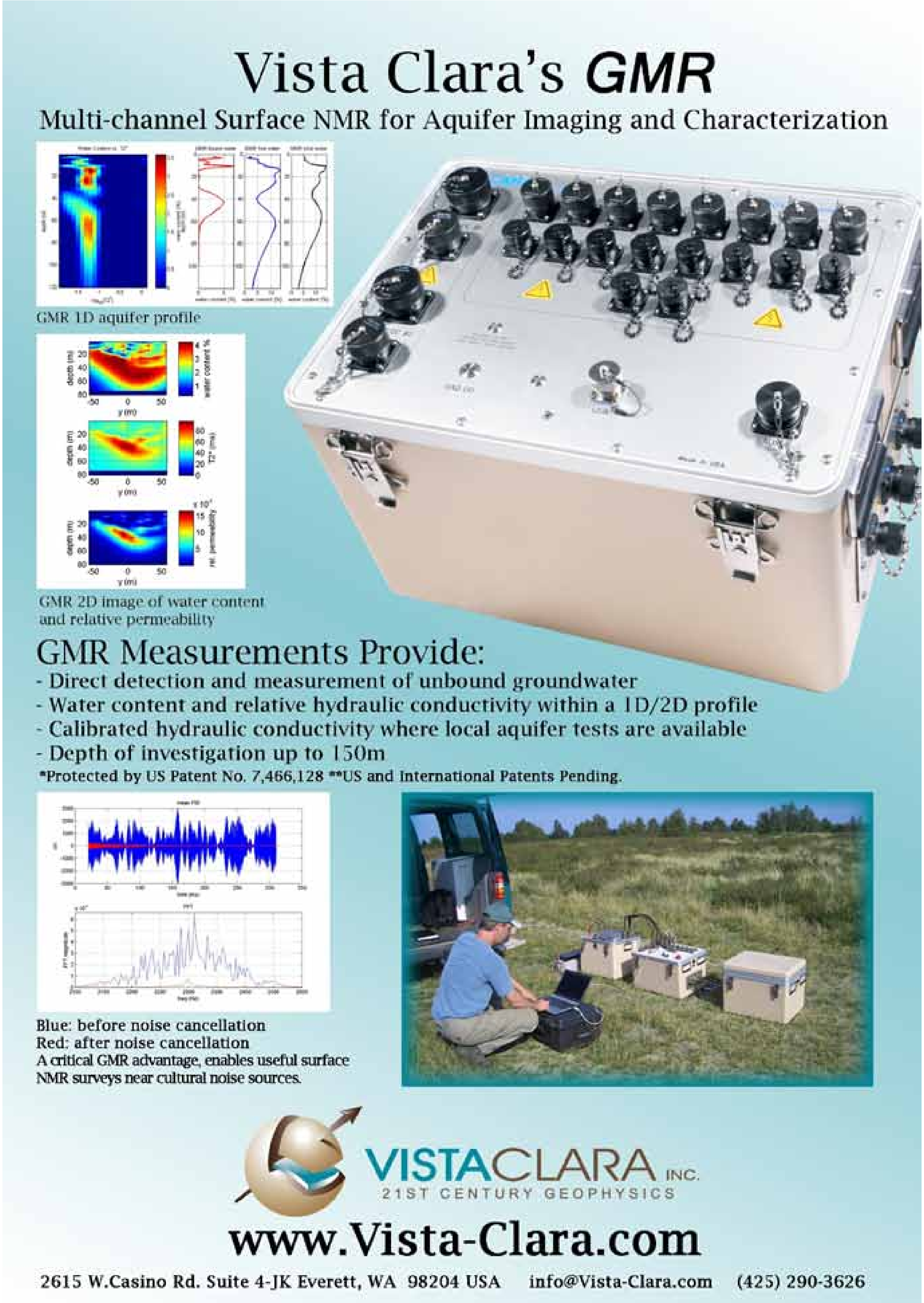
Seismographs • Magnetometers
Geoelectrical Instruments

Sales & Rentals

www.geometrics.com

GEOMETRICS
Innovation • Experience • Results

P: (408) 954-0522 · F: (408) 954-0902 · E: sales@geometrics.com
2190 Fortune Drive · San Jose, CA 95131 U.S.A.


Vista Clara's GMR
Multi-channel Surface NMR for Aquifer Imaging and Characterization
GMR 1D aquifer profile
GMR 2D image of water content and relative permeability
GMR Measurements Provide:
- Direct detection and measurement of unbound groundwater
- Water content and relative hydraulic conductivity within a 1D/2D profile
- Calibrated hydraulic conductivity where local aquifer tests are available
- Depth of investigation up to 150m
*Protected by US Patent No. 7,466,128 **US and International Patents Pending.
Blue: before noise cancellation
Red: after noise cancellation
A critical GMR advantage, enables useful surface NMR surveys near cultural noise sources.
VISTACLARA INC.
21ST CENTURY GEOPHYSICS
www.Vista-Clara.com
2615 W.Casino Rd. Suite 4-JK Everett, WA 98204 USA info@Vista-Clara.com (425) 290-3626

GPR

GSSI provides the most versatile GPR systems on the market today. The success of our data acquisition products is the result of nearly 40 years as the world leader in the development of ground penetrating radar.

- Rugged, field-worthy control systems and antennas
- Antenna frequency range from 16 to 2600 MHz
- Military spec connectors on all cables
- User-friendly software
- Easy GPS integration
- High-resolution, color displays
- All systems compatible with all GSSI antennas

Geophysical Instruments for Subsurface Investigation of the Earth and Infrastructure

EM

The Profiler EMP-400 is a frequency domain, electromagnetic profiling system. The user has the ability to simultaneously acquire data across multiple frequencies, providing the complete picture in less time.

The Profiler is easy to use, lightweight and built from the ground up to achieve unsurpassed signal stability.

- Geology
- Ground Water
- Archaeology
- Environmental Site Assessment

GSSI

The World Leader in Subsurface Imaging™

www.geophysical.com
sales@geophysical.com
800.524.3011

Calendar

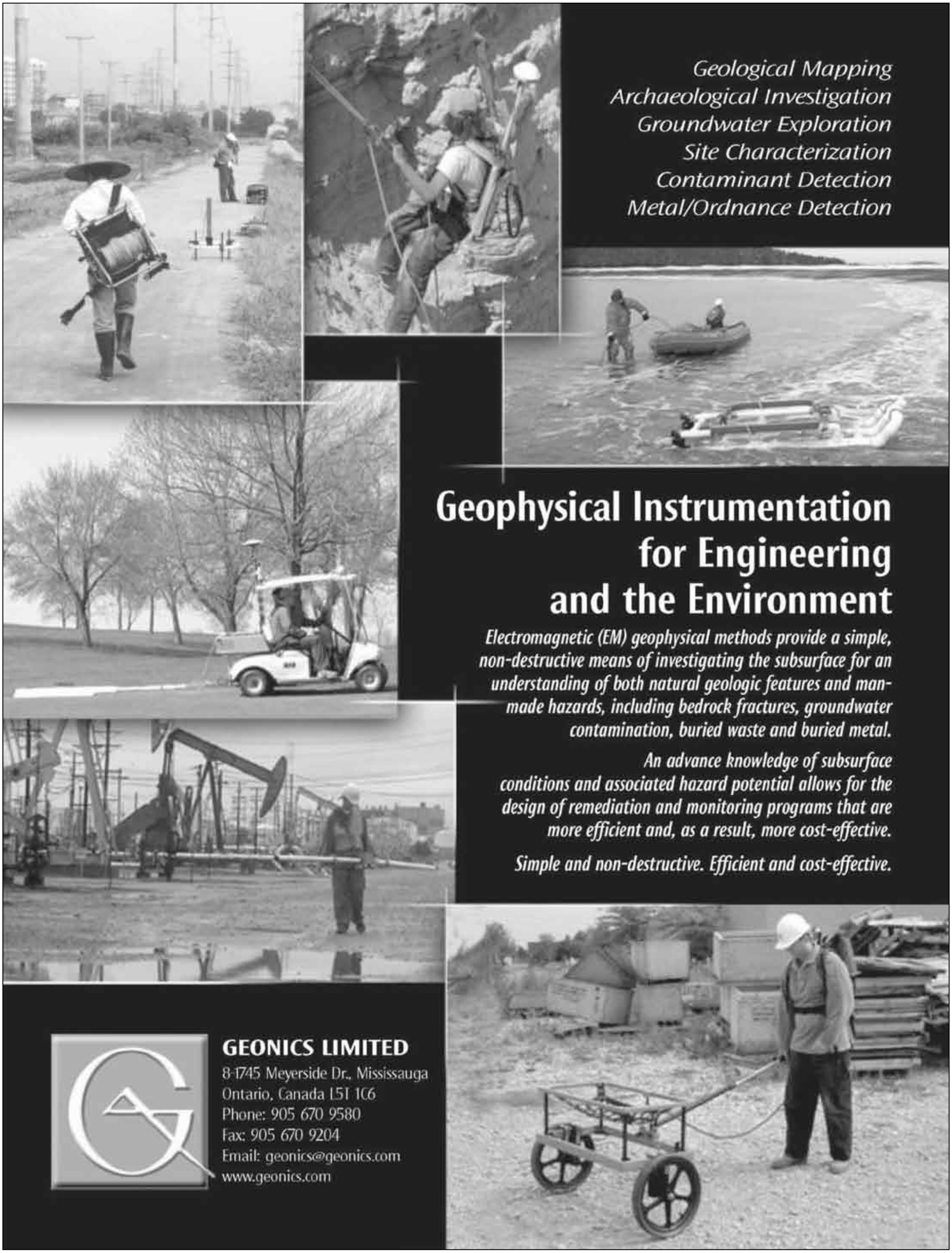
*Please send additions, errors, and omissions to a member of the **FastTIMES** editorial team.*

2010

March 15–18	*DGG 2010*: 70th Annual Conference of the German Geophysical Society, Bochum, Germany
April 11–15	*SAGEEP 2010*: Symposium on the Application of Geophysics to Environmental and Engineering Problems, Keystone, CO
May 24–26	*Geophysics at the Beach Symposium*: Newport Beach, California
May 31	Deadline for submission of articles, advertisements, and contributions to the June issue of *FastTIMES*.
June 14–17	*ICEEG 2010*: 4th International Conference on Environmental and Engineering Geophysics, Chengdu, China
August 22-26	*ASEG/PESA 2010*: 21st International Conference & Exhibition of the Australian Society of Exploration Geophysics, Sydney, Australia
August 31	Deadline for submission of articles, advertisements, and contributions to the September issue of *FastTIMES*.
September 5–10	*IAEG 2010*: 11th Congress of the International Association for Engineering Geology and the Environment, Auckland, New Zealand
October 17–22	State-of-the-Art in Multi-Dimensional Electromagnetics: A Special Session in Honor of Gerald W. Hohmann, Denver, CO
November 30	Deadline for submission of articles, advertisements, and contributions to the December issue of *FastTIMES*.

2011

January 10–14	*12th Multidisciplinary Conference on Sinkholes and Engineering and Environmental Impacts of KarstTM*, St. Louis, Missouri
February 28	Deadline for submission of articles, advertisements, and contributions to the December issue of *FastTIMES*.
April 10–14	SAGEEP 2011: Symposium on the Application of Geophysics to Environmental and Engineering Problems, Charleston, SC


Geological Mapping
Archaeological Investigation
Groundwater Exploration
Site Characterization
Contaminant Detection
Metal/Ordnance Detection
Geophysical Instrumentation for Engineering and the Environment
Electromagnetic (EM) geophysical methods provide a simple, non-destructive means of investigating the subsurface for an understanding of both natural geologic features and man-made hazards, including bedrock fractures, groundwater contamination, buried waste and buried metal.
An advance knowledge of subsurface conditions and associated hazard potential allows for the design of remediation and monitoring programs that are more efficient and, as a result, more cost-effective.
Simple and non-destructive. Efficient and cost-effective.
GEONICS LIMITED
8-1745 Meyerside Dr., Mississauga
Ontario, Canada L5T 1C6
Phone: 905 670 9580
Fax: 905 670 9204
Email: geonics@geonics.com
www.geonics.com

President's Message: A Different Kind of SAGEEP This Year

Jonathan Nyquist, President (nyq@temple.edu)

The deadline for SAGEEP abstracts is just around the corner (December 18th) so I'd like to take a moment to reflect on what will be different about our annual meeting this year.

First, the requirements for SAGEEP papers have changed. There has always been a love/hate relationship expressed by SAGEEP contributors. Some academics complain that SAGEEP papers are too burdensome to write, "I can go to AGU or SEG having written no more than an abstract. If I take the trouble to write 10-page paper I am going to submit it to a journal, not a conference proceeding." Others enthuse, "SAGEEP volumes are absolutely the best source of state-of-the-art case histories!" In truth, many of these studies will never appear in journals because outside of academia there is little incentive to endure the lengthy process of peer-review and revision. Well, our current guidelines can accommodate submissions both long and short. The new "extended abstracts" can be anywhere from a few pages to a full length paper. The only limitation is that the final PDF with figures should be under 4 MB so everything fits a single CD.

Second, planning the technical sessions has been different this year. In the past, the Technical Chair has simply waited for all the papers to arrive and then sorted them into sessions. This year, the SAGEEP planning committee brainstormed to come up with exciting themes for sessions and then encouraged session chairs to invite the experts. General submissions are welcome as always. The invitation process is simply intended to encourage lively, informative sessions, and to recruit new speakers to SAGEEP.

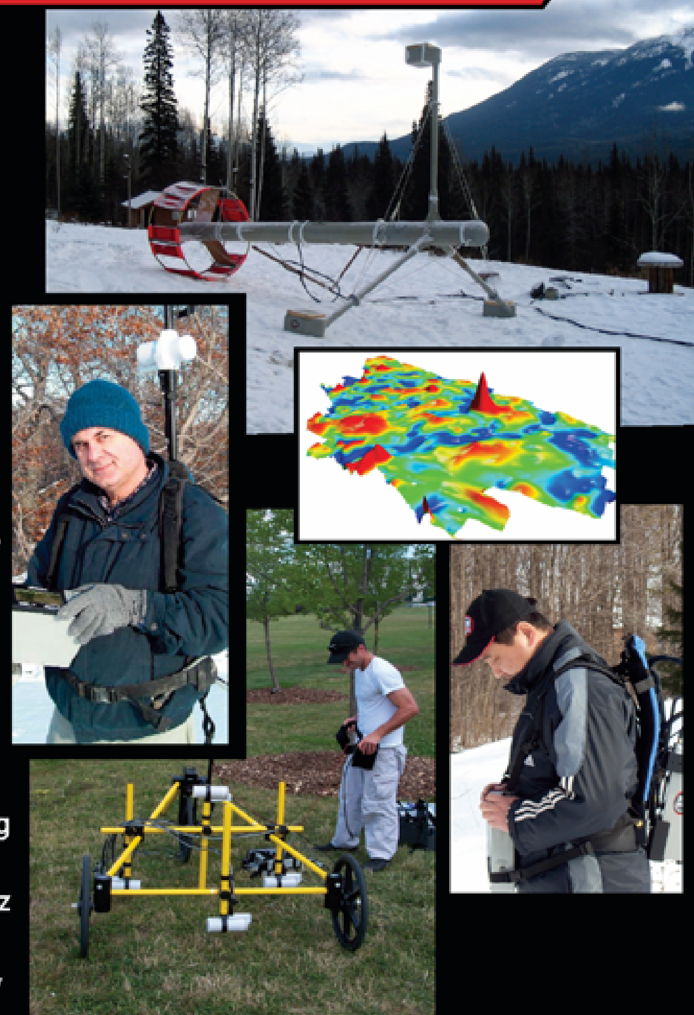
Finally, the venue this year is not your typical hotel and meeting rooms. Keystone is a lovely resort and conference center high in the Rocky Mountains west of Denver (http://www.keystoneresort.com). Some of us old-timers are trying to recapture the memories of a wonderful SAGEEP held there in 1996. The site is beautiful, the resort offers a wide variety of restaurants and activities, and off-season rates are very affordable. Although it's springtime in the Rockies, a nearby ski area will still be open for those who want to begin or end their trip taking a run down slopes.

SAGEEP this year will be more than a meeting, it will be a destination!

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 serving SAGEEP papers from the EEGS web site and support for the 2010 SAGEEP conference to be held in Keystone, Colorado. Contact Jon Nyquist (nyq@temple.edu) for more information.

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.

Find Your Solution

To work with diverse earth science challenges you can choose any of GEM's systems delivering clear benefits.

Web: www.gemsys.ca
Email: info@gemsys.ca
Phone: +1 905 752 2202

Our World is Magnetic.

WWW.GEMSYS.CA
GEM SYSTEMS
ADVANCED MAGNETOMETERS

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.

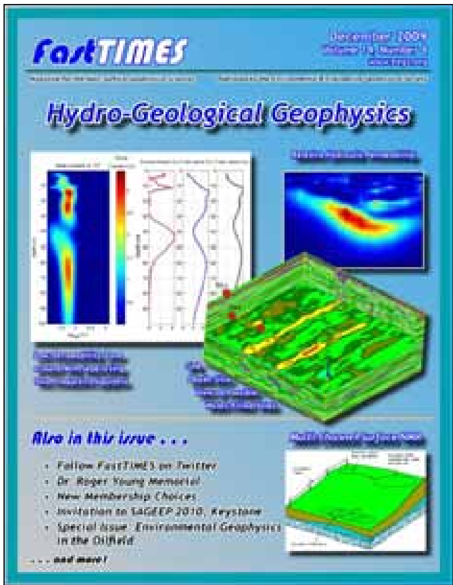
Descriptions of all the new membership options are outlined on EEGS' web site (www.eegs.org) in the membership section.

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, is sent by web link to several related professional societies, and is available to all for download from the EEGS web site at www.eegs.org/fasttimes/latest.html. The most recent issue (December 2009, cover image at left) has been downloaded more than 11,000 times as of March 2010, 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.

Help Support EEGS!

Please Join or

Renew Your Membership

Today at www.eegs.org!

SCINTREX

Setting the Standards

MICRO g LACOSTE

SETTING THE STANDARDS

The LaCoste Romberg-Scintrex Inc. (LRS) companies have a wealth of knowledge and have been conducting a combined business for over a century. This enables LRS to design and manufacture instrumentation that is worlds above the competition.

Contact us today and we will provide you the best solution for your requirements.

WORLD LEADERS IN

- Micro-Gravity Meters: Relative / Absolute / Dynamic / Borehole
- High Sensitivity Cesium Magnetometers / Gradiometers
- Proton Mag/VLF EM Systems
- Induced Polarization Receivers
- Resistivity Meters

APPLICATIONS

- Mineral Exploration
- Oil and Gas Exploration
- Environmental Site Characterization
- Civil Engineering
- Archeology
- Scientific Research
- Reservoir Monitoring

CG-5 GRAVITY METER
Land Gravity

SM-5 NAVMAG
Magnetic Mapping

SCINTREX
222 Snidercroft Road
Concord, Ontario, Canada L4K 2K1
Telephone: +1 905 669 2280
email: scintrex@scintrexltd.com
www.scintrexltd.com

AIR-SEA II
Dynamic Gravity System

FG-5 ABSOLUTE GRAVIMETER
The Standard in Absolute Gravity

MICRO g LACOSTE
1401 Horizon Avenue
Lafayette, CO, U.S.A. 80026
Telephone: +1 303 828 3499
email: info@microglacoste.com
www.microglacoste.com

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.*

Contents of the March 2010 Issue

Journal of Environmental & Engineering Geophysics
v. 15, no. 1, March 2010

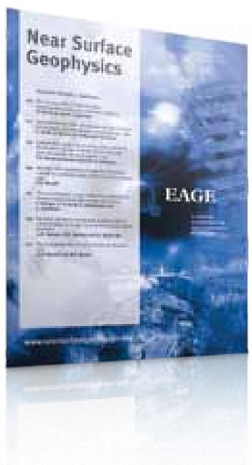
Editor's Scratch

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, April 2010

*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 August issue of EAGE's **Near Surface Geophysics** journal.*



EAGE
EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

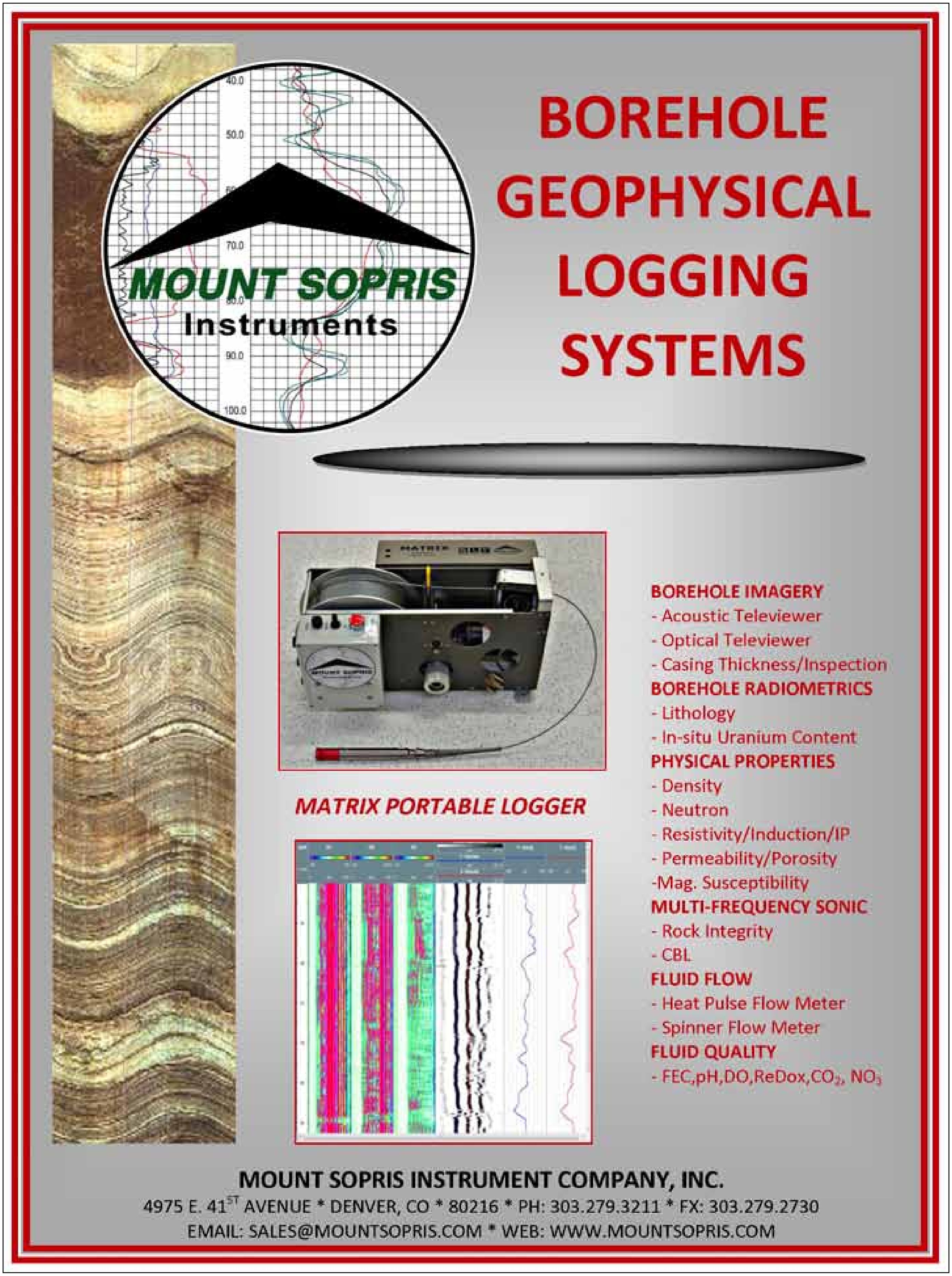
Near Surface Geophysics

Volume 8 · Number 2 · April 2010

Content

www.nearsurfacegeophysics.org

NSG-exchanged ad.indd 1 16-03-2010 13:10:08


MOUNT SOPRIS
Instruments
BOREHOLE
GEOPHYSICAL
LOGGING
SYSTEMS
MATRIX PORTABLE LOGGER
BOREHOLE IMAGERY
- Acoustic Televiewer
- Optical Televiewer
- Casing Thickness/Inspection
BOREHOLE RADIOMETRICS
- Lithology
- In-situ Uranium Content
PHYSICAL PROPERTIES
- Density
- Neutron
- Resistivity/Induction/IP
- Permeability/Porosity
-Mag. Susceptibility
MULTI-FREQUENCY SONIC
- Rock Integrity
- CBL
FLUID FLOW
- Heat Pulse Flow Meter
- Spinner Flow Meter
FLUID QUALITY
- FEC,pH,DO,ReDox,CO2, NO3
MOUNT SOPRIS INSTRUMENT COMPANY, INC.
4975 E. 41ST AVENUE * DENVER, CO * 80216 * PH: 303.279.3211 * FX: 303.279.2730
EMAIL: SALES@MOUNTSOPRIS.COM * WEB: WWW.MOUNTSOPRIS.COM


SPIDAR - Revolution in GPR
Network an unlimited number of GPR systems
Sensors & Software
subsurface imaging solutions
www.sensoft.ca, sales@sensoft.ca, Tel: (905) 624-8909, North America: 1-800-267-6013

***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 software developed to process and interpret near-surface geophysical data.*

MATGPR Release 2: A freeware MATLAB® package for the analysis & interpretation of common & single offset GPR data

Andreas Tzanis, Department of Geophysics, National and Kapodistrian University of Athens, Panepistimiopoli, Zografou 15784, Greece (atzanis@geol.uoa.gr)

Introduction

The Ground Probing Radar (GPR) has become an invaluable and almost indispensable means of exploring shallow structures for geoscientific, engineering environmental and archaeological work. At the same time, GPR analysis software is mostly proprietary and usually available from GPR manufacturers or a handful of other vendors. There are only three exceptions. A good but quite limited freeware package provided by the USGS (Lucius and Powers, 2002), which will not work in non-Microsoft platforms and due to the particularities of its graphics drivers has even problems working in Windows XP. Another freeware is the Radar Unix by Grandjean and Durand (1999), which is limited to Unix and Linux platforms; it does not work in Windows, OS(2) or Mackintosh systems unless they're augmented with the CygWin Linux emulator, and then under severe restrictions. Furthermore, RU draws processing power from the Seismic Unix (SU) analysis system, but as it is based on an outdated version of SU, it requires extensive overhaul. Both freeware packages are written in C/ C++ and are rather unwieldy to modification or augmentation by the average practitioner. The most recent arrival on the scene is the openGPR project of Matthias Schuh, Tuebingen, Germany. This can be found in the URL http://opengpr.sourceforge.net/?openGPR and is a rather impressive piece or work. Unfortunately, it works only in Linux OS and is heavily dependent on SU and a host of other support programs. It can be used by people who know their way about with computing.

With the references above aside, the academic free software community has been slow to react and the limited free software is usually focused on very particular problems (mainly data input / output), generally unorganized and so diversely programmed, that it cannot form a consistent basis for the reliable manipulation of GPR data. matGPR marks an effort to create a GPR analysis and interpretation package that can be truly cross-platform, as well as expandable and customizable with little programming effort. This is an ambiguous project, albeit feasible because MATLAB provides an all-inclusive high level programming environment that facilitates the development of advanced software, much easier and faster than building programs with conventional high level languages such as C, C++ or FORTRAN.

The appearance of MATLAB and its imitators made a big impact in the scientific community. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. To do this, MATLAB also introduced a new vector-oriented programming language, an interactive environment, built-in graphics and strict runtime error checking. These features offered many advantages and boosted productivity. MATLAB has since evolved to embed a large collection of state-of-the-art numerical tools, high quality graphics, object-oriented extensions, a built-in interactive debugger, web services and a host of other facilities. Of course, C and FORTRAN have also evolved, with some editions also acquiring high-level (visual) application development environments. However, neither offers as many facilities as MATLAB does, graphics for instance being a major issue. When it comes to effectiveness, what really matters is the efficiency of the entire process of realizing a new scientific idea, or creating an analysis and interpretation procedure. Arguably, MATLAB is overall much more efficient in this respect, facilitating the rapid prototyping of new algorithms or applications.

This paper comprises a presentation of matGPR Release 2 from a practical (user's) point of view. Programming and technical details will be given sparingly and the science behind the analytical methods will be limited to the bare essential; references, however, will be provided whenever possible, in the interest of completeness. The distribution bundle of matGPR comes complete with documentation: the "matGPR Manual and Technical Reference" and its HTML equivalent (on-line help). These documents amply explain the details of programming methods, analytical methods and execution procedures. In consequence, any description given herein will be complete but succinct: for additional information, the interested reader will be (implicitly or explicitly) referred to the "matGPR Documentation" whenever necessary.

General Features and Organization

matGPR is a two-layered software system, in which the bottom layer comprises a suite of functions to handle, display, inspect and process the data, while the top layer organizes these functions, automating data management and streamlining the flow of work.

The top layer and backbone of the program is realized in the form of the matGPR GUI (Figure 1). Data management decisions are made with the appropriate choices under the *Data* menu. Visualization

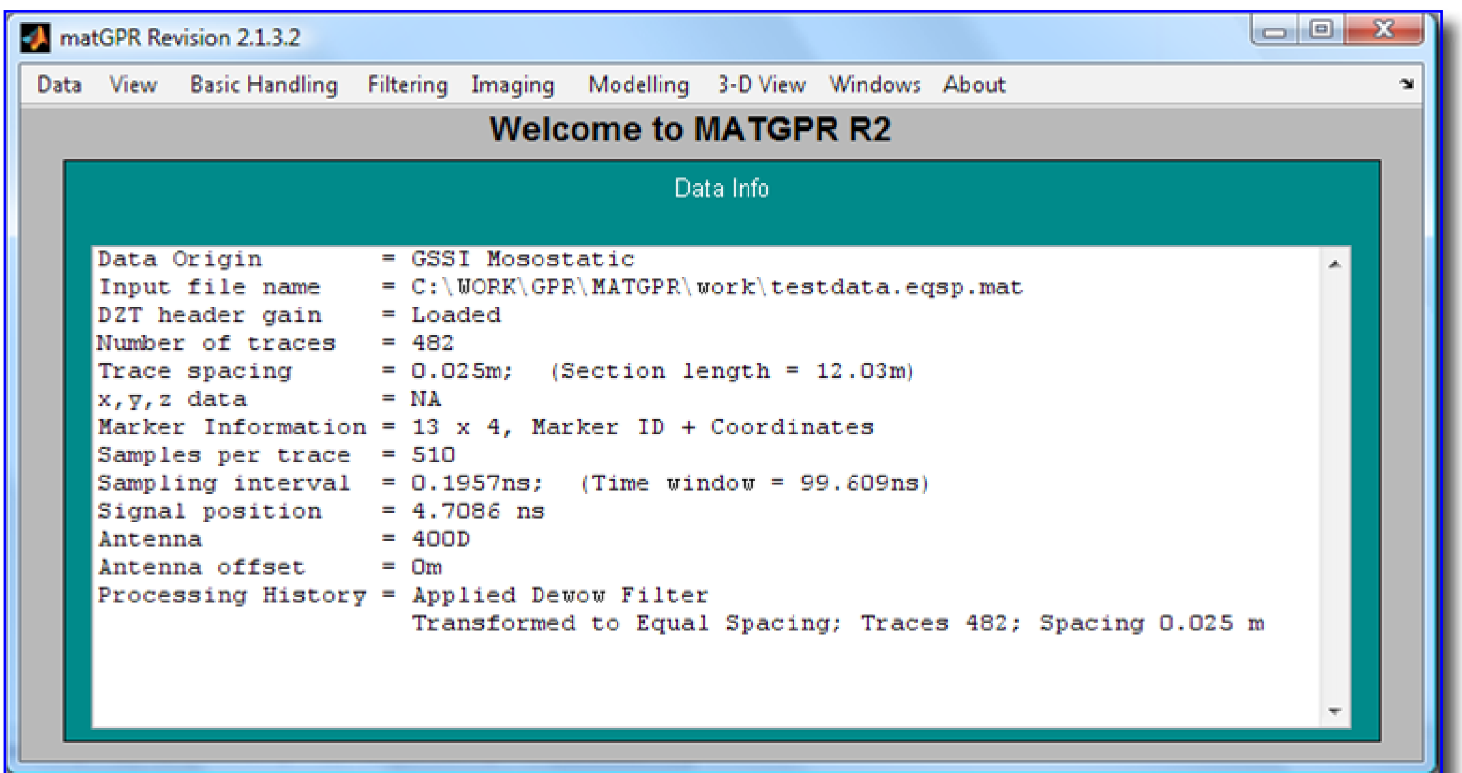


Figure 1. The matGPR GUI complete with information about the data being handled and its processing history.

and inspection is facilitated by utilities offered in the *View* menu, while processing and interpretation utilities can be found in the *Basic Handling, Filtering, Imaging* and *Modeling* menus. The *3D-View* menu provides a suite of functions to assemble, manipulate and visualize three-dimensional GPR data volumes and the *Windows* menu offers a fast navigation and window-switching service *exclusive* to matGPR. Finally, the *About* menu includes the *on-line help* and updater services.

The operation of the program is quite simple and succinctly outlined in Figure 2: work flows in a continuous cycle between the current *Input Data*, i.e. that data before some processing operation (step) and the *Output Data*, i.e. the data resulting from this operation. One may import, display and inspect the Input Data with the appropriate choices under the *Data* and *View* menus. Then one decides and applies a processing step and displays/ inspects the result, i.e. the Output Data. If satisfied, one keeps (holds) the result, replacing the Input Data with the Output Data and repeats the cycle with a new

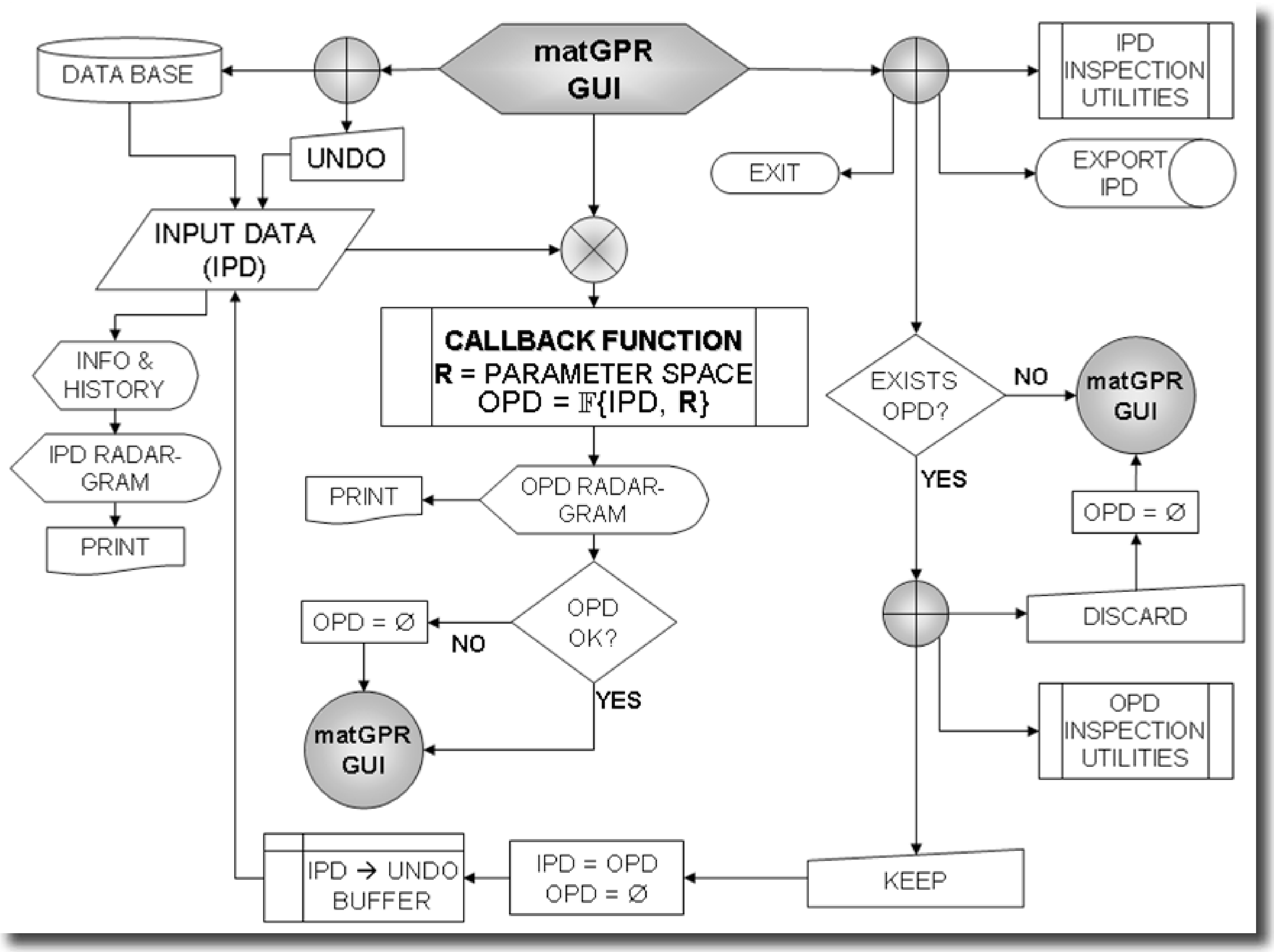


Figure 2. The flowchart of a data analysis session with matGPR.

processing step. If not, one may discard the result and cycle with another processing step. A *multi-level* undo/ restore utility is available at any time at which control is returned to the matGPR GUI. The Input Data may also be saved/ exported via the matGPR GUI. Soft and hard copies of the Input and Output

Data (and any figure produced during a session), can be made at any time using the *FigureTools* menu of the figure windows (see below).

The Input Data is held in a data structure named IPD (for Input Data) and the Output Data in an identical data structure named OPD (for Output Data). In addition to the radargrams (data) the IPD/ OPD structures hold detailed spatial, temporal and archiving information, including the processing history. Some of this information is projected in the matGPR GUI (Figure 2). Details can be found in the matGPR Documentation.

The IPD and OPD structures are accessible through MATLAB's base workspace and can be used or manipulated independently. For example, their fields can be input/ output to the user's own, or third party processing functions, while the results will still be available to matGPR for further manipulation. Essential information about the Input Data is displayed in the matGPR GUI and is updated after each and every processing step.

matGPR is a modular program With the exception of the management and direct visualization utilities each module performs a self-contained operation and comprises the Callback function of the corresponding menu item and its accessory I/O or analysis function. In Figure 2, the Callback function is displayed as a subprogram which includes (calls) the analysis function $\mathbb{F}\{\mathrm{IPD},\mathbf{R}\}$, where **R** is the set of parameters required for the execution of $\mathbb{F}\{\bullet\}$. Although it may appear redundant to have a Callback function execute an analysis function instead of calling it directly, this scheme facilitates flow control operations such as consistency checking and error trapping, as well as data management. It also allows the I/O and analysis functions to be used independently (e.g. from the MATLAB Command Window), or without the restrictions imposed by the matGPR data structures (e.g. with different data or in an altogether different program).

Now, consider that M-code (MATLAB's language) executes rather slowly, on account of being interpreted and not compiled. This may be a serious shortcoming when it comes to computationally intensive tasks. However, MATLAB offers three solutions:

1. It makes an honest effort to use an efficient programming style: for many applications, vectorized and well-written M-code is as fast as compiled code, to the point of being competitive.

2. It can integrate fast, compiled C or FORTRAN code with M-code by means of the MEX-file concept. The FORTRAN-MEX sources are included in the distribution bundle, so that the MEX-file may be (re)built if its functionality is somehow lost.

3. It provides a set of alternative (computationally intensive) functions that drive external, stand-alone FORTRAN executables to do the number crunching.

Details about which processes use MEX-files or alternative functions and how to implement them can be found in the matGPR Documentation.

The modular architecture of matGPR allows one to expand the program with new analysis modules easily and without having to know many details about the program's infrastructure. At any rate, familiarity with the MATLAB language and graphical object manipulations in particular, is necessary. The matGPR documentation provides detailed instructions of how to expand the program.

It is possible to *undo* a number of processing steps in order to restore the data to a previous state. A GUI displays the history of the data and the user may specify any previous state to which it will be restored (Figure 3). The number of processing steps that may be undone is adjustable; the default is 4, which seems to be a good compromise for Windows XP OS with 2GB of core memory. The previous processing steps stored in the Undo Buffer can be removed to reclaim memory.

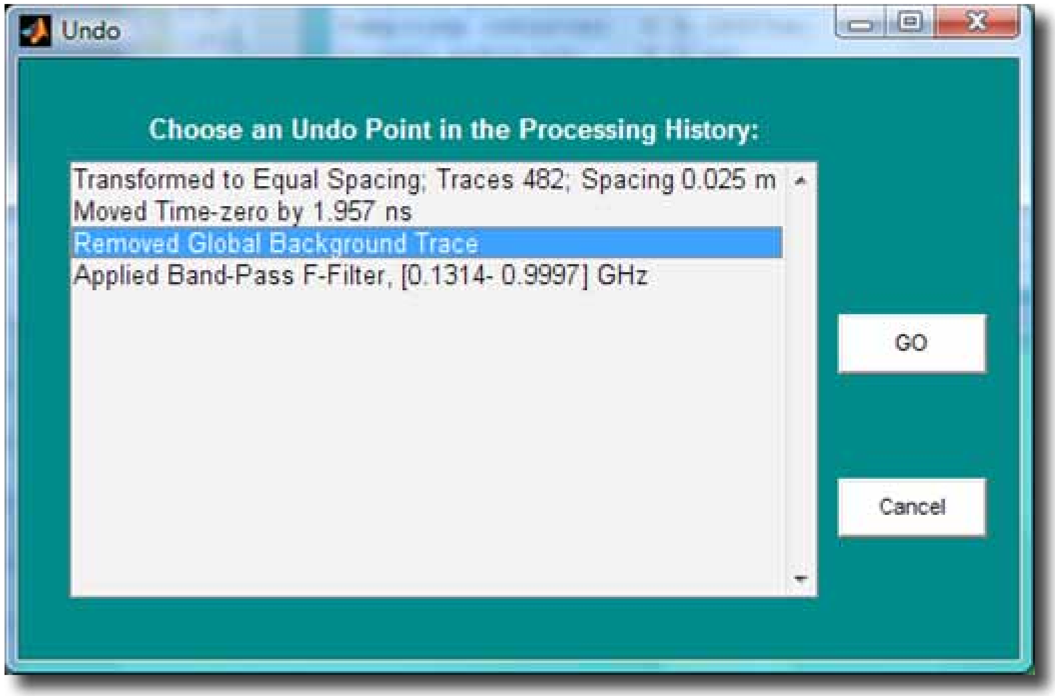


Figure 3. The *Undo* GUI. On pressing GO, the IPD will be restored to the highlighted state of its processing history.

Data Formats and I/O operations

In matGPR, the term *"raw data"* defines data sets that exist in the GPR manufacturer's native storage format and *prior* to importing /converting to the matGPR data structure format. At present, matGPR can import raw data written in the formats of the GPR manufacturers GSSI (RADAN/ DZT), Måla Geophysics (RAMAC/ RD3), Sensors and Software (PULSE EKKO/ DT1) and ZOND (SEG-Y). *Only single-channel* data files are acceptable, inasmuch as matGPR is currently being offered for zero- or single-offset surveys. With respect to bistatic Pulse Ekko (DT1) data, only data recorded in "reflection" mode (single-offset) are fully supported. Multiple-offset data can be imported and displayed, but cannot be processed save for rudimentary editing and filtering.

In addition to the above, matGPR uses the SEG-Y Revision 0 and 1 Data Exchange Formats to import/ export data: it can import data written in both Revision 0 and Revision 1 styles but will export data in Revision 1 style only. These formats are widespread in exploration geophysics and have been adopted as the preferred method of archiving or exchanging data. This is also the reason why matGPR does not export to proprietary file formats (RADAN, RAMAC, etc.). The format used by CWP's *Seismic Unix* package – the SU format – is also supported (see http://www.cwp.mines.edu/cwpcodes/); this is a simplified version of the SEG-Y Rev.0 format. Additional and extensive information about the implementation of the SEG-Y and SU standards exist in the matGPR Do-cumentation.

Finally, matGPR implements two specific binary files formats and also implements MATLAB's standard MAT-file format for interim I/O operations. The matGPR-specific formats are identified by the extensions

.mgp and *.m3d* and are considerably more compact, packing the same information in less than half of the space required by MAT-files. The MGP-file and MAT-file formats are used to store the IPD structure (MGP is the default). The M3D-format is used for storing large 3-D data volumes. The structures of the MGP- and M3D-files are dully described the matGPR Documentation.

Once read, the raw data is automatically saved in MGP-file or MAT-file binary format. The save destination folder is the parent directory of the raw data file. By default, *all* subsequent output operations concerning the derivate (processed) data sets will be directed to the parent directory of the raw data file, which thus becomes the home directory of the data analysis project. The *home directory* can change only by importing data from a different directory.

Consecutive or broken GPR sections can be joined (*concatenated*) into a single data set, provided that all data sets are in MGP or MAT format and have the same number of samples per trace, the same sampling rate and the same trace spacing. The operation also applies to unequally spaced data taken with instruments without survey wheels, or prior to marker interpolation. Marker trace information is preserved during concatenation. Finally, depth migration marks the end-point of a data processing line. At present, there's practically nothing more that can be done with matGPR that would be theoretically correct and would extract meaningful information. Accordingly, depth migrated data can only be saved to a binary file, for future use (e.g. concatenation or generation of 3-D data volumes for interpretation).

Data Visualization

The visualization of radargrams includes image (color-coded) displays with an assortment of color schemes, wiggle-trace displays and variable-area displays, as well as combined image/wiggle or image/variable-area presentations. The mode of display is selectable through the Settings sub-menu. The Input Data is displayed in the *GPR Data* figure. The *Processed GPR Data* figure displays the Output Data; it is created whenever a processing step is taken and destroyed when the Output Data is held or discarded, or another processing step is taken. Figure 4 shows the Input Data in "image" display mode; examples of alternative display modes can be found in the matGPR Documentation.

matGPR provides a dedicated menu to change and manipulate the colors of "images", the *ImageColours*. The available color schemes include some of MATLAB's native "colormaps" like *grey, bone, jet* and *hot*. In addition, there are three custom color schemes dubbed *Blue – Red* (varying smoothly from navy blue to white and from white to brick red), *Brown – Black* (varying from brown to white and from white to black) and *Red – Black* (varying from brick red to white and from white to black). These are useful for emphasizing the higher amplitude reflections while masking low amplitude noise. The default colormap is jet (rainbow). It is also possible to manipulate the color schemes by adjusting the *Colour Saturation* (contrast) via a slider GUI, increasing/ decreasing brightness, reversing color order and interchanging color indices.

Another feature of matGPR's visualization complement is the *FigureTools* menu, which provides utilities for handling graphical objects. The MATLAB Figure Menu contains a large collection of utilities organized in tool bars; some of those may be useful in rare circumstances and some may actually not apply in the context of matGPR, for instance lighting a 2-D image. *FigureTools* provides a concise collection of the Figure Menu's tools and utilities that every user would like to have readily available while doing away with the rest. However, if one must access some feature of the Figure Menu (for instance advanced annotation utilities), it is always possible to recover it from within *FigureTools*. The collection of graphical object handling tools provides for: Color scheme editing specific to the current figure (as opposed to the global color manipulation utilities available through *ImageColors*, zooming, panning, data inspection, exportation of the current figure in any of the formats supported by MATLAB, printing, and editing the current figure/ axes and their child objects.

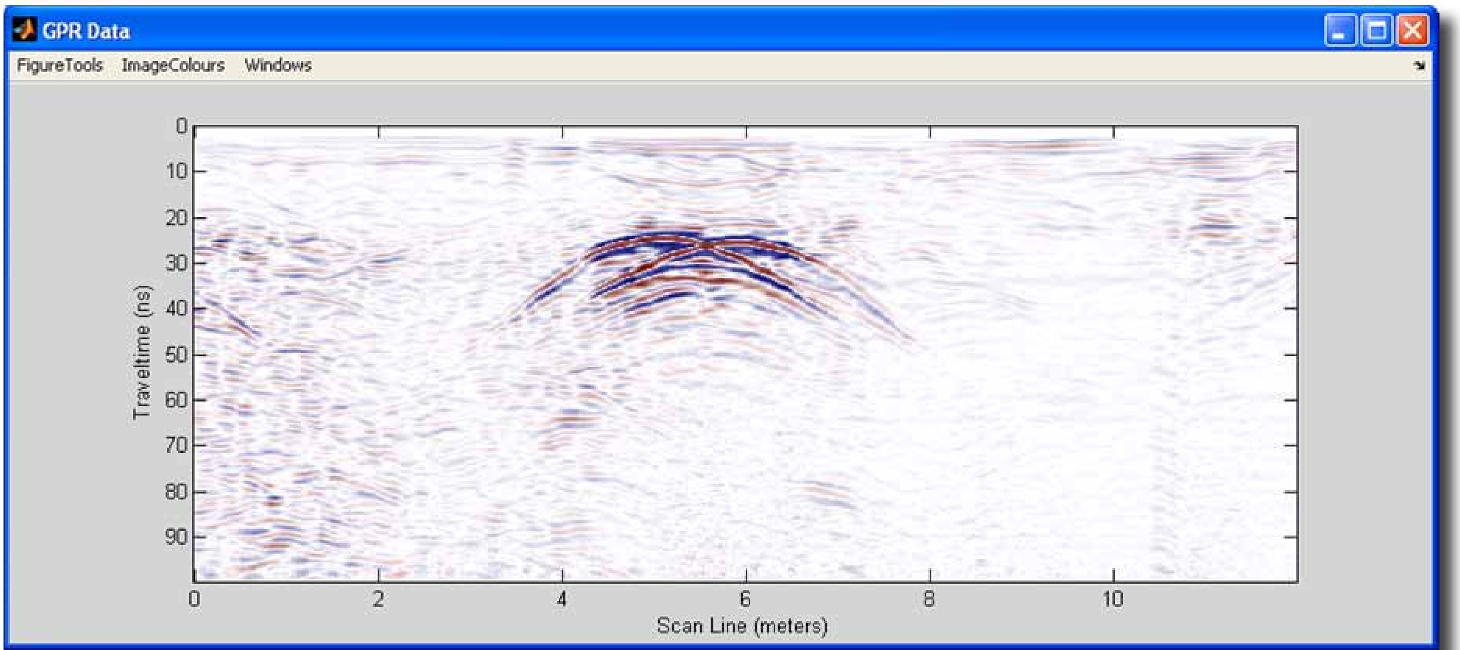


Figure 4. The GPR Data figure presenting the IPD in image display mode (Blue-Red color scheme). The OPD is displayed by an iden-tical figure.

Additional visualization tools include utilities to scrutinize the data. The Trace Viewer and the *Spectra Viewer* respectively facilitate inspection of the traces and Fourier amplitude spectra of the Input/ Output Data. A particular characteristic of matGPR is the *Attenuation Characteristics* viewer. The program computes the instantaneous power of all traces in the IPD or OPD data, hence the median and the mean power attenuation functions (median and mean instantaneous power). It also determines best fitting models for power-law and exponential attenuation based on the median attenuation function. Finally, it displays the attenuation functions and the best fitting attenuation models as per Figure 5. The result of this operation allows insight into the attenuation characteristics of the GPR signal, hence the properties of the medium; it also facilitates gain

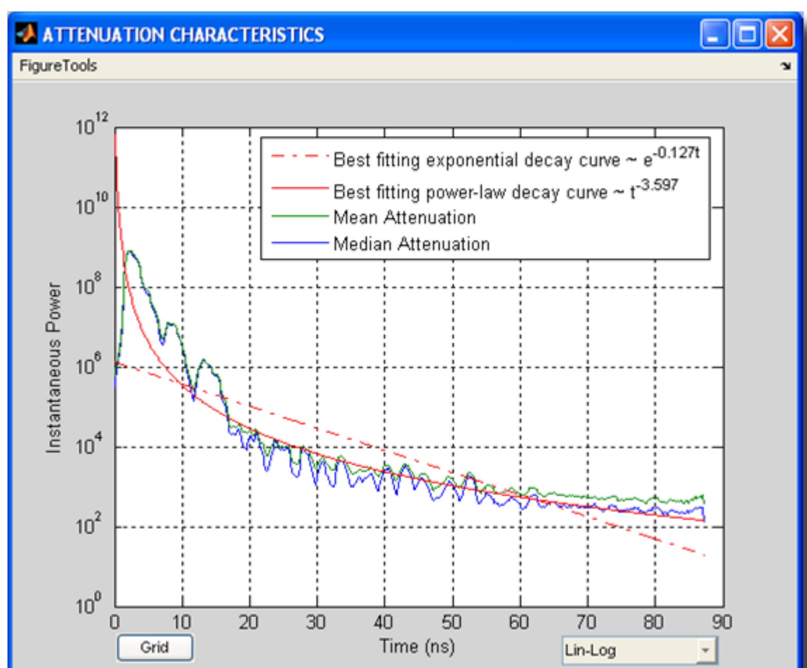


Figure 5. The *ATTENUATION CHARACTERISTICS* figure displays the median and mean power attenuation functions and the best fit-ting power-law and exponential decay models.

manipulations. Finally, it is possible to display the instantaneous attributes of the radargrams in the form of “images”. The instantaneous amplitude of the input sequence is the amplitude of the analytic signal. For GPR data it measures the reflectivity strength, reducing the appearance of random signal. Moreover, one may view the instantaneous phase angle of the Input Data, the unwrapped phase angle of the analytic signal and the instantaneous frequency (i.e. the time rate of change of the instantaneous phase angle).

Editing and Basic Processing

Basic data handling includes basic radargram editing (including resampling), gain manipulation, and, for GPR instruments not equipped with survey wheels, transformation of data collected at equal-time spacing mode to data at equal-distance spacing. The latter suite of functions also facilitates the three-dimensional positioning of traces with respect to some local co-ordinate system.

Trace Editing Utilities

Time-zero (or *Signal Position*) adjustment allows control of the instant of the surface reflection, i.e. the time when the radar pulse enters the subsurface (time zero). The ‘blank’ data between the beginning of a trace and time-zero is usually stored as part of the data. The post-acquisition determination and adjustment of time-zero amounts to a static correction and matGPR facilitates the operation via a modification of the *Trace Viewer* utility. It is also common for the later parts of the traces to contain useless noise occupying valuable memory; matGPR allows one to reduce the size of the radargram along the temporal dimension by discarding late-time arrivals (*Time-Window Trimming*). In combination with the *Signal Position* utility, this is also useful for extract-ing a certain part of the data for some specific purpose. Along the same vein, the *Edit Scan Axis* utility reduces the size of the radargram by discarding groups of traces at the beginning or at the end of the section’s scan axis (scanline). It is also used to extract groups of traces or even large parts of the section to a separate data set; a GUI facilitates the operation, as detailed in the matGPR Documentation.

Very often, the acquisition protocols oversample the data in both the temporal and spatial dimensions, sometimes by an excessive amount. In other cases, the sampling rate should be increased, for instance to unify data sets collected with different instruments and acquisition protocols. Since the original signal is always assumed to be band-limited to half the sampling rate, (otherwise aliasing would occur), Shannon’s sampling theorem says that the signal can be exactly and uniquely reconstructed for all time from its samples, by *band-limited interpolation*. The flexible and effective public-domain algorithm of Smith and Gosset (1984) takes care of this problem and allows sampling rate conversion by *any* rational factor.

GPR field systems frequently generate errant (bad) traces or groups of traces, for instance due to the antenna(e) coupling with local ground features or bouncing on small obstacles. It is possible to eliminate such traces using the *Remove Bad Traces* utility. The bad traces can be picked by pointing and clicking and are subsequently re-placed with interpolants computed from their near neighbors. Because this function uses interpolation, it works best for *isolated* bad traces, or small clusters of traces; it is *not* recommended for removing extended groups of bad traces, as it will probably yield unreliable interpolants.

General Conditioning Utilities

These include removing the dc component (arithmetic mean) from each trace in the radargram (de-meaning), eliminating wow with zero-phase high pass filtering at exactly 2% of the Nyquist, and *Trace Equalization*. The latter makes the sum of the absolute values of all samples in a *reference* trace the *same* for all traces; a GUI allows selection of the reference, which can be the first trace, the mean trace, the median trace, any trace specified by the user or, finally, any positive number (base value).

Signal Amplification

matGPR offers four different data amplification methods, each with its own merits. *Automatic Gain Control* (AGC) is a process by which gain is automatically adjusted in a specified manner, as a function of a specified parameter, such as signal level. In matGPR, the time-varying signal level is measured by the RMS amplitude computed over a sliding time-window. By scaling the amplitude of the data at the centre of the window with respect to the RMS amplitude of the window, the process ensures that ranges of low amplitudes are emphasized with respect to ranges with high amplitudes. Two variants of AGC are provided: The *Standard AGC* where the window is a boxcar function and the *Gaussian-tapered AGC* where the boxcar is weighted (tapered) with a Gaussian bell function, whose breadth depends on noise level (input parameter). This emphasizes the contribution of the data around the centre of the window, thus producing a more focused result.

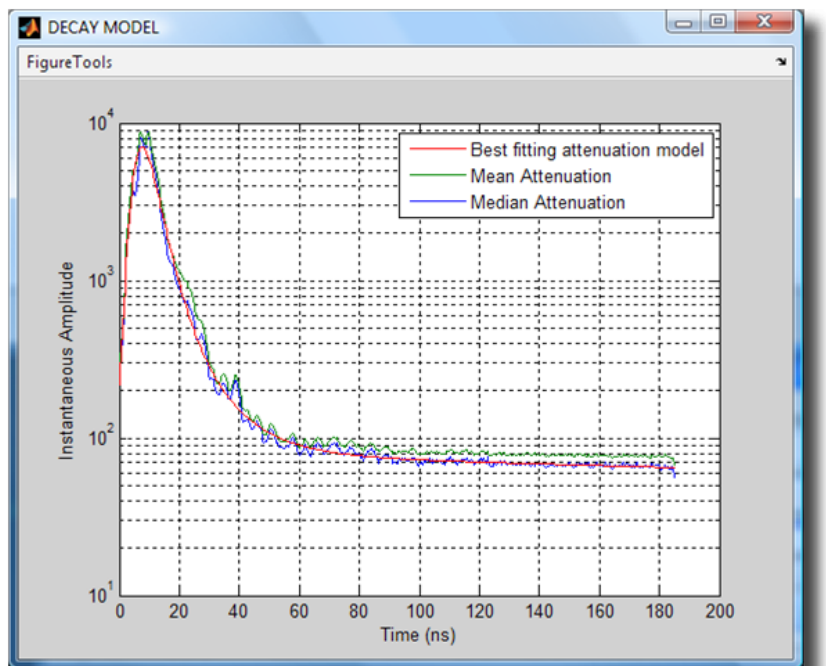


Figure 6. The result of the Inverse Amplitude Decay analysis.

The *Inverse Amplitude Decay* process applies an empirical gain function, which exactly compensates the mean or median amplitude attenuation observed in a GPR section. First the analytic signal for all traces is computed, whence the median and the mean instantaneous amplitude attenuation function is derived (Figure 6). The best fitting median and mean attenuation models are then computed using an exponential spectral function of the form $A(t) = c_1.\exp(-a_1 t) + c_2.\exp(-a_2 t) + \ldots + c_N.\exp(-a_3 t)$ with N linear parameters and N non-linear parameters. By means of a floating menu, the user may experiment with the *order N* of the fitting function and explore the merits of using the median or mean amplitude decay curve to obtain an optimal gain function. The gain function is the normalized inverse of the preferred amplitude decay model, $g(t) = [\,A(t) / \max\{A(t)\}\,]^{-1}$.

The *Inverse Power Decay* process applies a gain function of the form $g(t) = scale \times t^{power}$ and may also be used for the so-called spherical divergence correction. The user is asked to supply the power. Prior to this, the program computes and displays the attenuation characteristics of the input data and a best fitting power-law attenuation model as per Figure 6. Then, it suggests a *power* which is the *exponent of the best-fitting model less 1*. This is usually a very good solution, but experimentation may provide a result more suitable for the data. The scale is computed automatically.

Experience shows that for zero-mean and time-zero adjusted data, the suggested *power* is around 2 and the observed attenuation is around 3. From a practical point of view, *power* ~ 3 applies little gain, or even attenuates the early (near surface) arrivals, while applying too much gain and emphasizing the late arrivals. On the other hand, *power* ~ 2 apportions higher gain at the early parts of the time window and lower gain at the late parts, providing for a more balanced eventual distribution of amplitudes. Claerbout (1996, pp. 222-223) gives a theoretical justification for using *power* = 2 in seismic data. He shows that the basic geometry of energy spreading predicts a single power of time for the spherical divergence correction and argues that an additional power arises from a simple absorption calculation: This justification has not been demonstrated in the case of GPR data; it is a theoretical exercise for the future, but nevertheless worth noting!

Marker Interpolation and Trace Positioning

For GPR instruments without survey wheels or other automatic triggering devices, matGPR provides a suite of marker interpolation utilities, so as to transform data collected in equal-time spacing mode, to data at equal-distance spacing. Key to this operation is the marker information matrix (MIM) stored in the IPD structure. On importing raw, unequally spaced data with Marker Traces, the MIM will comprise a single column vector with the sequential numbers of the Marker Traces. To be useful for interpolation, the MIM must be augmented to a 4 column matrix, so as to include the x-, y- and z-coordinates of the Marker Traces; this is done with utilities suitable for either regularly or irregularly spaced Marker Traces (details can be found in the matGPR Documentation). The MIM may also be exported/ imported separately to/from an ASCII disk file.

Once the MIM is prepared, (either in the IPD or on disk), it is possible to transform data collected at equal-time spacing mode, to data at equal-distance spacing using the *Interpolate to Equal Spacing* option of the *Basic Handling* menu. The interpolation routine uses the piecewise cubic Hermite polynomials method. The MIM is also the basis for generating the x, y and z coordinates of the radargram traces, thus including topographic information into the data set. Prerequisite is that the Input Data has equally-spaced traces. This is also done with interpolation and comprises the *Make X Y Z* utility of the *Basic Handling* menu. The output x, y and z coordinates are stored in the IPD structure.

Filtering and Advanced Processing

matGPR offers a variety of smoothing and processing facilities which can be generally classified in the broader categories of spatial filters, frequency and wavenumber filters and deconvolution filters. There's also a specialized Radon domain filter (τ-p filter). These utilities are collected under the *Filtering* menu of he matGPR GUI and will be briefly presented below.

Spatial and Low Dimensional Subspace Approximation Filters

The most rudimentary noise suppression utilities available in matGPR are *Mean* and *Median Smoothing Filters* in one and two dimensions. The filters are applied by sliding a given filter window over a 2-D data wall. The data value corresponding to the central element of the window is substituted by the mean or median of the window data. Zero padding is applied; therefore, the edges of the output data are expected to be distorted. For the same reason, the size of the smoothing window should be kept reasonably small.

A second suite of classical and simple spatial filters, suitable for crude separation of data components with different spatial characteristics, involves *foreground/ background trace manipulation* and comprises:

- *Global Background Removal*. The global background trace is actually the mean trace determined by adding all traces together and dividing by the number of traces. This is a stacking process that reduces randomly varying signal (e.g. reflections from the subsurface) and enhances coherent signal, for instance horizontal banding (system noise). Caution is required when handling data with strong natural horizontal reflectors.

- *Horizontal Event Suppression*. The mean (background) trace of a sliding window is subtracted from the data in the window. This will eliminate small horizontal features (coherent event signal) and may be used to ex-pose reflections (events) that dip at high angles.

- *Dipping Event Suppression*. Conversely to the above, this removes the foreground traces: the background trace is assigned to the centre trace in the sliding window (rather than being subtracted from the data). This will remove high-angle reflections (a dip filter), for instance to expose the sub-horizontal hydrogeologic features more clearly.

The Karhunen–Loeve (KL) transform (Karhunen, 1946; Loeve, 1955; Fukunaga, 1990), is a preferred method for approximating a set of vectors or images by a low dimensional subspace. In matGPR the approximating subspace is defined in terms of the first (largest) *N* singular values and associated singular vectors of the Input Data. The KL transform of the data is re-synthesized from the *N* largest singular values and vectors. The appropriate value of *N* should be determined by experiment. On output, matGPR displays the reconstructed model of the data (e.g. Figure 7 top), and the residuals after subtracting the model from the input data (Figure 7 bottom). When *N* is reasonably large (e.g. 3-10% of the shortest data dimension), the model is a smooth version of the input data, exhibiting enhanced lateral coherence of the GPR events. When *N* is very short, the model comprises only the most powerful principal components of the input data. In Figure 7

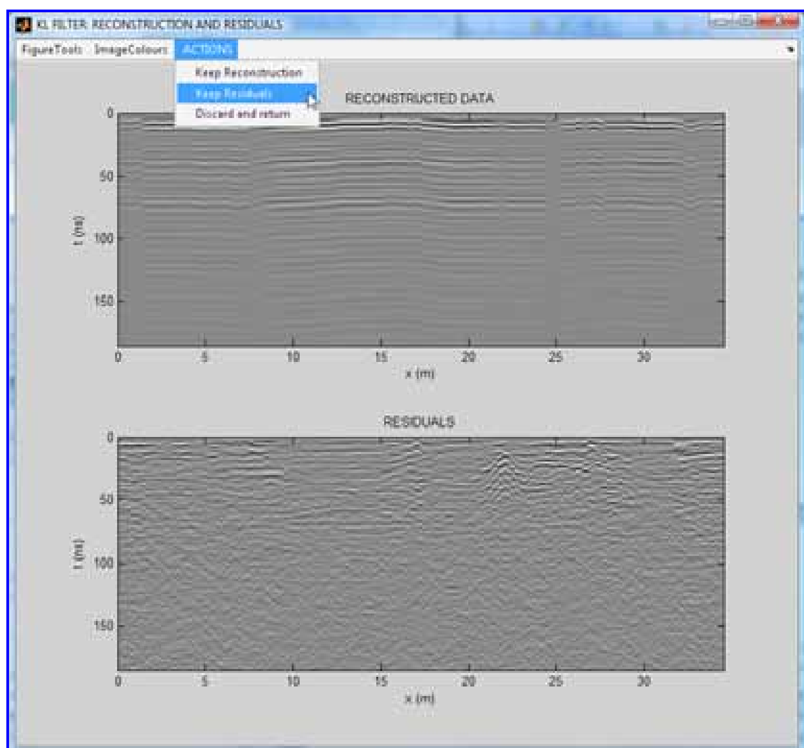


Figure 7. Low dimensional approximation of a data set using only the first 2 principal components. The top panel displays the reconstructed model. The bottom panel shows the residual of subtracting the model from the data.

N=2; the model contains only *strong* horizontal reflections and ringing and the residuals represent a version of the data free of powerful and unwanted interference.

Frequency and Wavenumber Filters

matGPR provides a suite of frequency domain (F), wavenumber domain (K) filters and frequency-wavenumber domain (F-K) filters. The F- and K- filters are identical, the only difference being in the sense they're applied (time-wise vs. scan axis-wise). The simple strategy employed in matGPR is to construct a very long FIR wavelet (at least 75% of the data length) in order to achieve very narrow transition bands, while eliminating Gibbs effects and ripple structure. The filter is applied in the frequency (wavenumber) domain and in a forward and a backward sense, so as to preserve phase information. All types of filters (low/ high pass, band pass and band stop) are available. There are three ways to design the filters:

1. *Graphically, on a test trace or scanline:* matGPR prompts the user to pick a test trace or scanline and displays its power spectrum as per Figure 8 (blue line). The cut-off frequencies are picked by pointing and clicking. The spectrum of the filter is then displayed as per Figure 8 (red line), together with the spectrum of the filtered data (green). The user may then apply or discard the filter and repeat the process.

2. *Graphically, on the mean trace:* The filter is designed based on the spectrum of the average trace or scanline computed from the Input Data, following the same procedure as above.

3. *By direct input* of the cut-off frequencies in an appropriate dialog box.

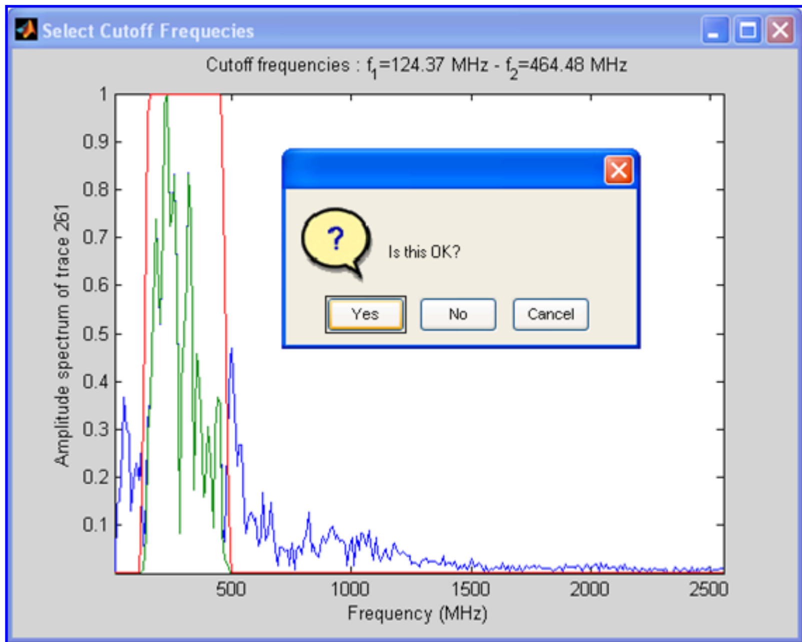


Figure 8. An F-filter is applied to the test trace. The program displays the result and awaits instructions.

The *F-K filters* may be zone-pass or zone-stop, fan-filters (velocity range pass/ stop) and up-dipping/ down-dipping event separators. The desired option is selected via a floating menu.

Zone-pass/ stop filters work like band-pass/ stop filters. The user is required to define a polygonal area (*zone*). Zone-pass operators retain the F-K spectral contributions *in* and *on* the sides of the zone; zone stop operators work the opposite way. There are two methods to define the zone, also selectable via a floating menu:

- Import the coordinates of the zone from an ASCII disk file (as specified in the matGPR Documentation).

- Set the coordinates graphically, on-screen: matGPR displays the log-amplitude of the F-K spectrum as per Figure 9 and the vertices of the polygonal zone are set by left-clicking at the desired (F, K) position. To facilitate the process, the cursor coordinates are displayed at the bottom of the figure, the vertices are marked and the enclosed area is outlined with a transparent rubber band. Incorrect clicks can be undone by middle-clicking the mouse. Right-clicking completes the design and applies the filter.

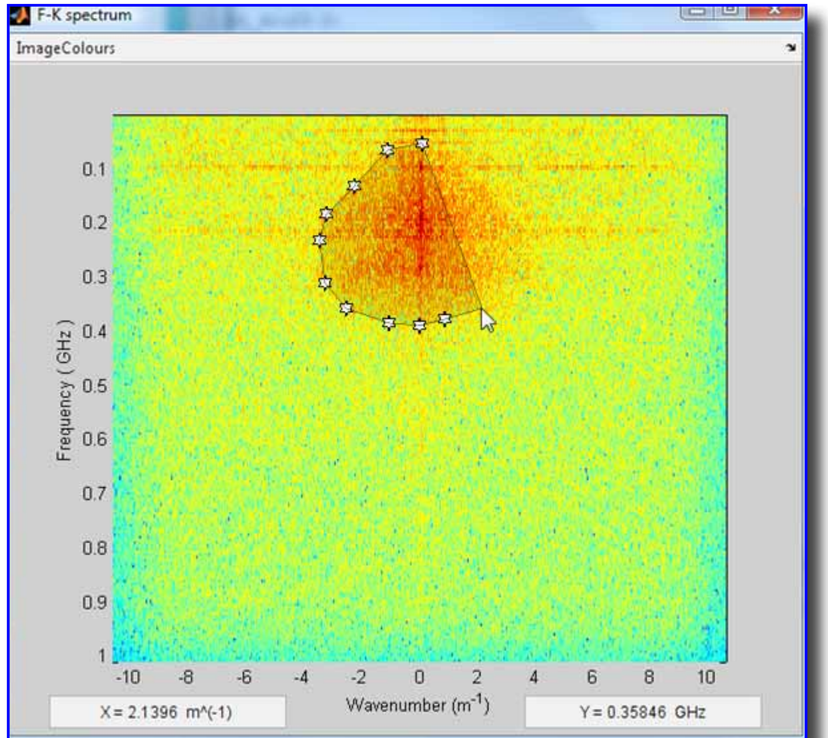


Figure 9. F-K filtering: Graphical assignment of a polygonal zone. This F-K spectrum belongs to the data of Figure 23.

Velocity range pass / stop provides for fan filtering in the F-K domain. The user must define the [upper, lower] negative and [lower, upper] positive apparent velocity limits in an appropriate dialog box. For *Velocity Range Pass*, the spectral contributions *inside* the fan will be retained and vice versa for *Velocity Range Stop*. The positive and negative velocity bounds do not need to be symmetric, but then caution is necessary because aliases may be introduced.

Up/ Down-dipping event separation. The F–K transform has the property that reflections with positive slope (up-dipping) map into the positive-K half, while reflections with negative slope (down-dipping) map into the negative-K half. Therefore, by muting an entire half-domain, it is possible to reject reflections dipping in one direction or the other: the result is a section with features having unique dip directions.

Deconvolution Filters

F-X Deconvolution is a method of random noise cancelation in the frequency-space domain, first proposed by Canales (1984) and Gulunay (1986). The data is transformed into the F-X domain. For each frequency, Wiener filtering with unity prediction in *space* is used to model the data and the model is re-mapped onto the T-X domain. Credits for the F-X deconvolution routine go to M.D. Sacchi, University of Alberta; only minor changes have been effected for compliance with matGPR. For additional information see http://www-geo.phys.u-alberta.ca/saig/SeismicLab.

Predictive deconvolution is a very well known exploration seismology process, frequently used for the suppression of multiples or reverberations.

Sparse-spike deconvolution attempts to find an Earth reflectivity series r consistent with the observed data series y in the sense $y = f * r$ and exhibiting the *minimum* possible number of reflectors; f is a given source wavelet. By design, sparse deconvolution emphasizes the larger amplitudes and more important events in the observed data, while suppressing small amplitude or spurious events and noise. matGPR implements the procedure described by Sacchi (1997). On output, matGPR displays both the *model* $\hat{y} = f * r$ in which the more significant events have been retained and the recovered reflectivity series r. The user may then decide whether to use the model, or the reflectivity as outcome of the operation. Credits for the sparse deconvolution routine go to M.D. Sacchi, University of Alberta, with minor changes effected for compliance with matGPR.

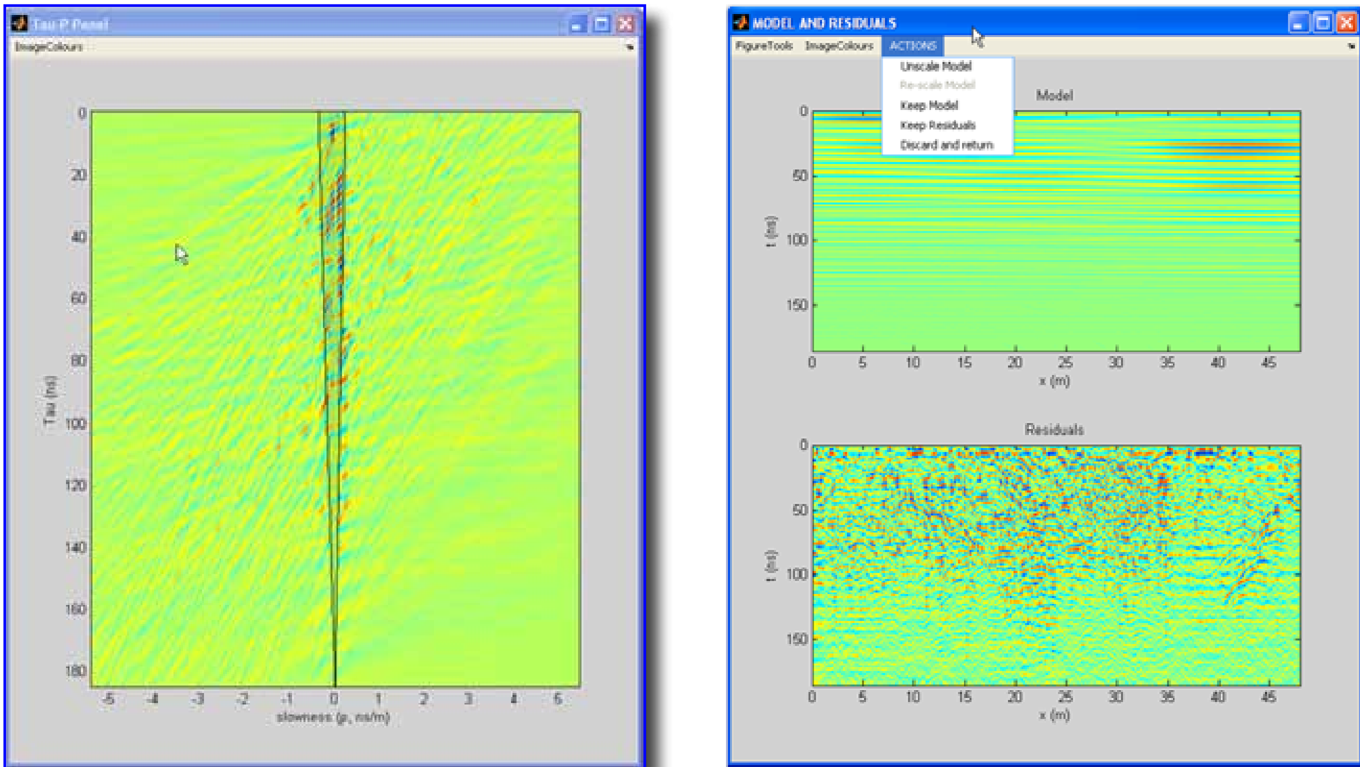


Figure 10. **Left**: The τ-*p* panel of the data shown in Figure 23. The shaded area represents the pass-zone containing the main contributions of the horizontal banding effects. **Right**: A model of the ringing computed by inverse transforming the τ-*p* elements within the pass zone (top) and the residual of subtracting the model from the data (bottom) 23.

Tau-p Filter

This is a simple application of Radon domain filtering. The radargram is transformed to the τ-*p* domain by integration in the T-X domain. A model of the data (noise) is extracted by muting τ-*p* domain contributions outside (inside) a pass (stop) polygonal zone and inverse transforming to the T-X domain also by integration. The resulting model (residuals) is taken to comprise the filtered data section. There are only two options, Zone-pass or Zone-stop filtering. As with F-K filters, there are two methods to define the zone: import the predefined coordinates from an ASCII disk file, or set the coordinates on-screen. Figure 10 shows the application of τ-*p* filtering to the data of Figure 23, in order to remove ringing effects (see §10 for details). In the left panel, the ringing is modeled in the τ-*p* domain by muting all contributions outside the shaded pass-zone. Upon inverse τ-*p* transformation, matGPR displays the model, (in this case the ringing effect), and the residuals (Figure 10 Right). By means of the ACTIONS menu, the user may decide whether to keep the model, or the residuals as the outcome of the τ-*p* filtering process. The residuals are more clearly seen in Figure 24 and are practically free of ringing.

Velocity Analysis and Imaging

matGPR offers a collection of imaging (migration) and modeling tools to assist in the interpretation. All these exercises require velocity models, which are constructed with utilities presented below.

Notably, some migration routines incorporate frequency dependence of the phase velocity due to the frequency dependence of the dielectric constant, (resistivity and magnetic permeability are assumed to be constant). The calculation of fre-quency dependence follows the analysis of Bano (1996). matGPR also provides a utility to manually calculate phase velocities, namely the *Simple Velocity Calculator* under the *Imaging* menu. It is probably worth noting that the one- and two-dimensional velocity models are stored in corresponding fields of a dedicated data struc-ture (VS), which is directly accessible via the MATLAB Workspace. The composition of VS is dully explained in the matGPR Documentation.

Velocity Analysis and Static Corrections

In matGPR, at present, *"velocity analysis"* implies the manual fitting of diffraction front hyperbolae based on the premise of non-dispersive propagation in a uniform halfspace and targets comprising point diffractors, or finite sized objects with quasi-circular cross section. The *Fit Diffraction Hyperbola* procedure (Figure 11) displays the Input Data in image display mode; parameters involved in the fitting process are the halfspace *Velocity*, the *Radius* of the target and the coordinates of its centre (*Depth* and *Location* along the scan axis). The parameters can be changed interactively, a) using the slider UI controls shown at the bottom of Figure 11, b) by clicking the *middle* mouse button at the *apex* of a diffraction hyperbola and turning the scroll-wheel to *automatically* adjust velocity and depth, or, c) using both methods above.

The calculated hyperbola is plotted on the data and the quality of fitting is determined by the eye, (depends on the experience of the user). Clicking on the DONE button causes the current value of the halfspace velocity to be assigned to the appropriate field of the velocity data structure, whence it is accessible by the imaging functions.

Static (topographic) corrections may be applied with the *Static Correction* option under the *Imaging* menu. The routine initializes a GUI, in which the necessary parameters are specified (ground velocity, sense of the correction (up or down) and elevation datum). The elevation data necessary for the corrections are provided through the IPD and should have been prepared with the *Make X Y Z* procedure (see §5).

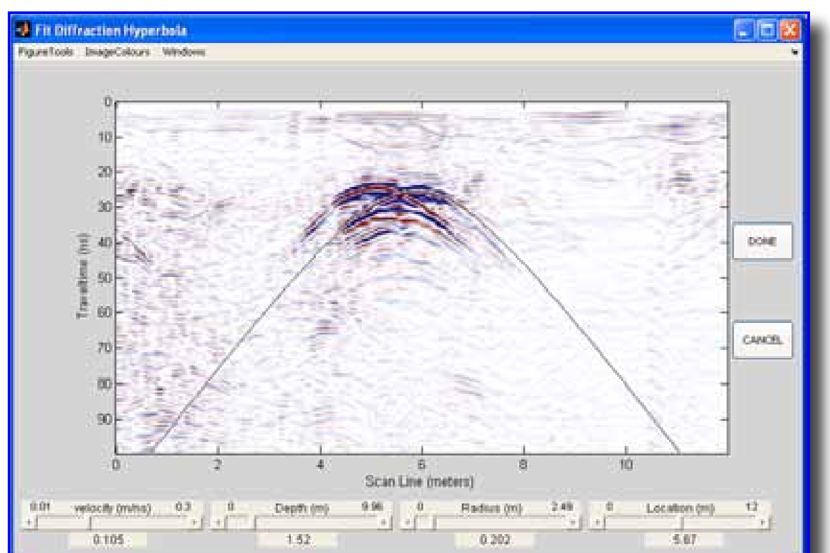


Figure 11. Interactive fitting of a diffraction front hyperbola.

1-D Time and Depth Migration

The layered velocity model necessary for the one-dimensional migrations may either be imported from a disk file (format specified in the matGPR Documentation), or supplied via an appropriate dialog box (the Get 1-D Velocity Model utility under the Imaging menu). The available methods are:

- Stolt's (1978) F-K migration for uniform or layered velocity structures (option *1-D FK Migration*). The routine uses Stolt stretching to account for non-uniform (layered) velocity structures and comprises a very compact and fully vectorized code, fast enough to outperform compiled implementations of Stolt migration.

- Gazdag's (1978) phase-shifting migration for uniform or layered velocity structures (option *1-D Phase-shift Migration*).

- One-dimensional depth migration (option *Time-to-Depth Conversion*). The algorithm implemented in matGPR follows a rather complex procedure. First, it computes a time vs. depth function *t(z)* from the velocity vs. depth function *v(t)* and inverts *t(z)* to *z(t)* by inverse linear interpolation. Next, it remaps *z(t)* to depth *z* and, based on this function remaps a trace *y(t)* to a trace *y(z)*.

2-D Depth Migration

The two-dimensional velocity model necessary for the two-dimensional depth migrations may either be read from a disk file, or generated by the *Get 2-D Velocity Model* utility after importing a synthetic structural model previously prepared by the *Model Builder* (see §8.1). The available 2-D migration options are:

- Gazdag and Sguazzerro's (1984), Phase-shift Plus Interpolation (PSPI) migration for zero-offset data, with lateral velocity variation. The PSPI migration routine uses only the non-dispersive phase velocity term because, at present, there's no accurate method to interpolate the dispersive terms in the sense required by the Gazdag and Sguazzero algorithm. Thus, PSPI migration should be used when there's some confidence that ignoring frequency dependence wouldn't cause any harm.

- The 2-D Split-step Migration algorithm by Stoffa et al. (1990), for Earth structures with lateral velocity variation, augmented to account for the frequency dependence of the phase velocity (dispersion). The default for matGPR is to include dispersion. The Split-step migration routine can be used independently of matGPR, in which case dispersion may be excluded by user intervention.

Modeling

matGPR includes two modeling methods: the fast, adjoint split-step approach of Bitri and Grandjean (1998) and the slow but precise Finite Difference method of Irving and Knight (2006). The modeling suite is complemented with the *Model Builder*, a GUI utility enabling construction of 2-D velocity models for the depth migration methods discussed above and the forward modeling methods presented below.

Creating Models

Figure 12 shows the menus of the *Model Builder*. The *Data* menu provides I/O functions and the *Actions* menu the tools by which to build and edit a model.

The model comprises an ensemble of objects with polygonal or circular cross-sections. The first object to enter the list is a uniform *background* with dimensions equal to the size of the model. The *Builder* will also

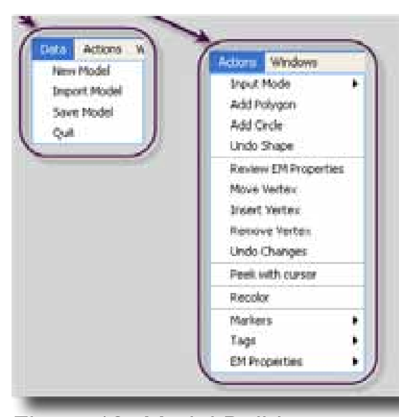


Figure 12. *Model Builder* menus.

enquire its properties and antenna frequency, calculate the phase velocity and ask for confirmation. An affirmative response prepares the *Builder* for new input.

There are three ways to enter a polygonal object, depending on the *Input Mode*. a) Graphically, where the vertices of the polygonal object are set by pointing and left-clicking at the desired coordinates. To facilitate design, the cursor coordinates are displayed at the bottom of the figure, the vertices are marked and the enclosed area is outlined with a translucent rubber band (Figure 13 left). If a vertex is incorrectly set, it can be erased by clicking the *middle* button. Right-clicking terminates the procedure. b) Through dialog boxes and, c) from ASCII disk files. When all the coordinates have been set, the *Builder* will paint the object and will inquire its properties and tag (which is then printed at the centroid of the object). After a new polygonal object is inserted, the *Builder* searches and snaps together the vertices of all object found to lie within 1% of each other.

Similarly, there are two ways to enter a circular object: Through dialog boxes by typing the coordinates of the centre and the length of its radius, and graphically by pointing and left-clicking first at the centre and then at a distance equal to the radius. The *Builder* then calculates a polygonal approximation to the circumference paints it on the model and enquires for its properties and tag.

The objects can be overlapping and the order by which they are introduced in the structural model determines the way they will appear in the velocity model (or if they will appear at all). The program adopts a front to back hierarchy: foreground objects will appear whole and background objects will appear partially if masked by foreground objects. Figure 13 (right) shows a model comprising a "trench" dug in the background, with a water pipe at (7, 2.5) meters, and a metal pipe at (13, 2) meters, both parallel to the strike of the trench.

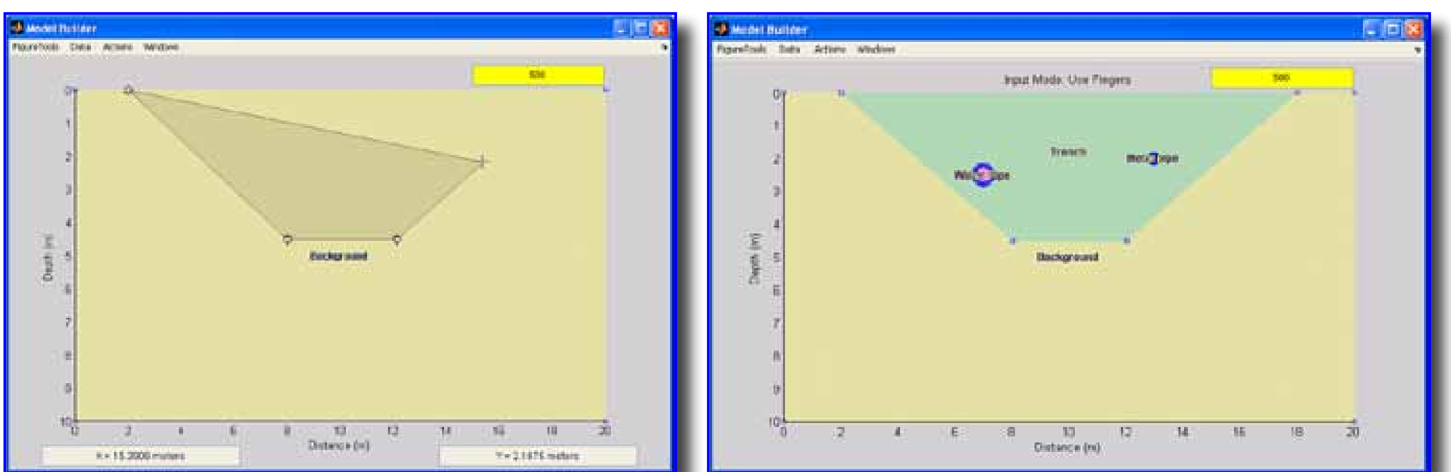


Figure 13. **Left:** Graphical insertion of a "trench" on top the structure. **Right:** Final model of the trench and two pipes.

Editing Models

The *Model Builder* allows extensive editing and modification of the model. The properties (dielectric constant, resistivity and magnetic permeability) of any object can be changed through *Review EM Properties* option of the Actions menu. The *Builder* projects a drop menu in which the object can be selected by its tag, (Figure 14), and then inquires the new properties through dialog boxes. Any object can be removed from the model also by selecting its tag in a similar drop menu (the *Undo Shape* option).

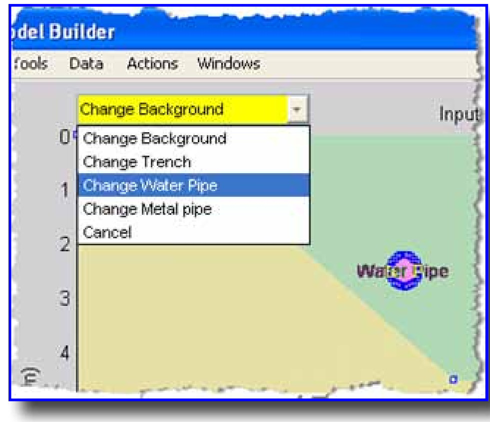


Figure 14. Drop down menu for selecting objects to edit their EM properties.

The geometry of polygonal objects can be changed by relocating (moving) or removing vertices and by inserting new vertices. This can be done either graphically, by pointing and clicking, or through dialogue boxes, depending on the *Input Mode*. Every time an object is modified, the *Builder* snaps together all vertices found to within 1% of each other. Modifications made in the geometry of an object may be reversed using the *Undo Changes* option. The model may be recolored at any time (the *Builder* assigns colors to objects *randomly* and sometimes the resulting scheme is dysfunctional). Finally, the *Actions* menu provides a set of functions to show or hide the vertex markers, show or hide tags and interchange tags with the corresponding EM properties.

The *Builder* saves the model for later access by itself, by the 2-D migration routines and by the Split-step and FDTD modeling programs. The format of the *model file* is free ASCII and is dully explained in the matGPR Documentation. It is simple enough and may be accessed/ modified independently, by any ASCII editor.

Split-Step 2-D Modeling

Synthetic GPR sections can be generated with the method of Bitri and Grandjean (1998). This is a fast and relatively dirty approach, lacking in detail (does not model secondary effects like multiples), and possibly prone to artifacts if applied indiscriminately. Conversely, it is efficient enough to effectively supplement the interpretation. The program will first ask for a model file prepared by the *Model Builder*. Based on the range of velocities it calculates from the model, it will compute and suggest a low, medium and high resolution grid for the synthetic radargram. It will also offer the choice of customizing the size of the synthetic radargram for particular requirements (e.g. simulation of observed data).

Experience shows that the high resolution synthetic is not necessarily the best choice, as it always comes at the expense of computing time. It does, however, exhibit the least amount of artifacts and aliasing. The low resolu-tion synthetic is computed quickly and is often acceptable, but depending on the model, it occasionally exhibits artifacts and aliasing. The medium resolution synthetic is often a good compromise. It should be noted that the dimension of the traveltime axis often tends to be overestimated and may be safely reduced through customization.

Finite Difference – Time Domain 2-D Modeling

Synthetic GPR sections may also be created with the TM-mode, Finite-Difference Time-domain method of Irving and Knight (2006). The program imports a model prepared by the *Model Builder* and constructs and displays an initial discretization of the model, as per Figure 15 (left). Based on this discretization, it computes and suggests *maximum permissible* values for trace spacing (*dx*) and depth spacing (*dz*) and requests confirmation/ modification of the parameters. The term “maximum permissible” refers to the values below which, aliasing effects should not appear! Based of the final values of *dx* and *dz* the final model grids are built. matGPR also requests the initial location of the source and trace (source) spacing along the scan axis. Finally, it suggests values for the sampling interval and length of the traveltime vector and requests confirmation.

matGPR offers the option to view the simulated E_y wavefield propagating through the model in real time. It is also possible to make AVI movies of the simulation. If real time viewing is selected, the progress is shown as per Figure 15 (right). Otherwise the progress is shown in a wait bar which is continuously updated with time-to-completion information.

The FDTD solution of the forward problem can be *quite slow*, especially when large models and high frequencies are involved. In the latter case, the size of the problem may overflow the memory allocatable by MATLAB. Normal sized problems may take several hours, even days to complete and it is advisable to run trial simulations before committing the system to heavy number crunching. The size of the model is very important in this respect and it is always recommended to scale it down with increasing frequency.

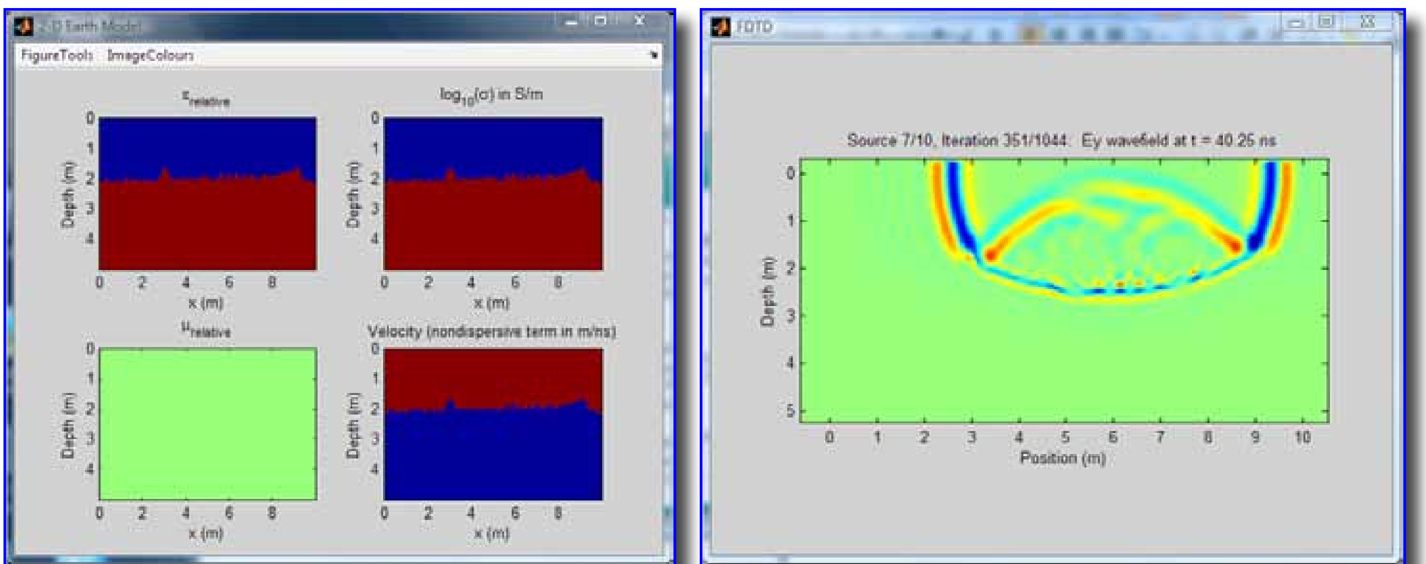


Figure 15. **Left:** Discretized material properties of the synthetic structural model (in this case an anomalous interface); dielectric constant (top-left), conductivity (top-right) and magnetic permeability (bottom-left); the non-dispersive term of the phase velocity is shown at the bottom-right panel. **Right:** The propagation of the Ey wavefield in the model can be displayed in real time.

Three-Dimensional Viewing

The presentation of matGPR will be completed with an overview of the 3-D visualization utilities, presently offered in the form of isometric surface and 3-D slice projections. These are only a first step toward assembling a more comprehensive set of 3-D visualization tools to facilitate the interpretation of complex data sets.

At present, 3-D data volumes may be generated from parallel 2-D radargrams; matGPR assumes that the data has been collected in a local co-ordinate system with the scan axis (longitudinal direction) parallel to the x-axis and perpendicular to the y-axis. The vertical axis can be either time or depth. The input profiles need not have the same lengths, or trace spacings, or traveltime vectors, or sampling rates, or depth vectors, or depth spacings; matGPR will homogenize the data with interpolation. Moreover, the profiles need not be equally spaced along the y-axis. The only acceptable data formats are the matGPR-specific MGP-files and MAT-files. It is imperative that the x- and y- coordinates of all traces have been assigned prior to the generation of the 3-D volume (see the *Make XYZ* utility of the *Basic Handling* menu in §5). A dedicated GUI helps to assemble the necessary data files.

If one or more 2-D radargrams have different sampling rates or trace spacings, or depth spacings, they are all automatically resampled with respect to the median of the corresponding parameter. Finally, if one or more ra-dargrams have different traveltime or depth vectors, or scan-axis lengths, the user is asked to decide whether to trim the longer data sets to the length of the shortest, or to zero-pad the shorter data sets to the length of the longest. The 3-D Volumes can be exported to an M3D-file and (re) imported to continue an interpretation ses-sion.

Isosurface Displays

An *"isosurface display"* comprises the presentation of 3-D data in the form of orthographic projections of (iso-metric) surfaces with equal signal amplitudes, or less rigorously stated surfaces of equal reflectivity. A typical example is shown in Figure 17. The attributes of the display are controlled by the GUI shown in Figure 16, the *Iso-Surface Display Controls*, which enable the specification of: a) The signal amplitude to be displayed, via the *Iso-Surface Value* slider and editable box. b) The viewing angle (*Viewer Position* panel) – free rotation is also possible by activating the *Free Rotate* checkbox. c) The axes aspect ratio (*Aspect Ratio* panel). The default is *x:y:z* = 1:1:10 and may be changed either by means of the respective editable boxes, or gradually using the *increase* (▲) or *decrease* (▼) push buttons. d) The direction of lighting (*Light Position* panel) and, e) the color of the iso-surface with the *ReColor* push button.

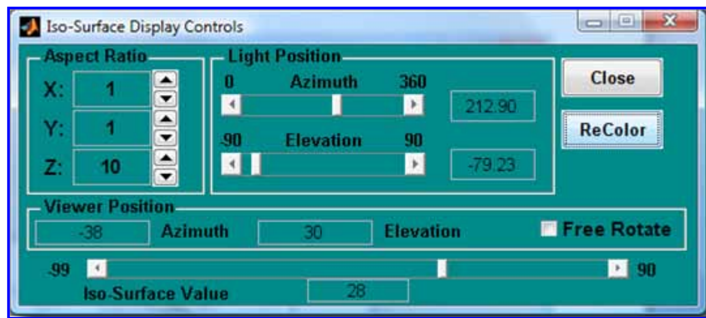


Figure 16. GUI to control isometric surface displays of 3-D GPR data volumes.

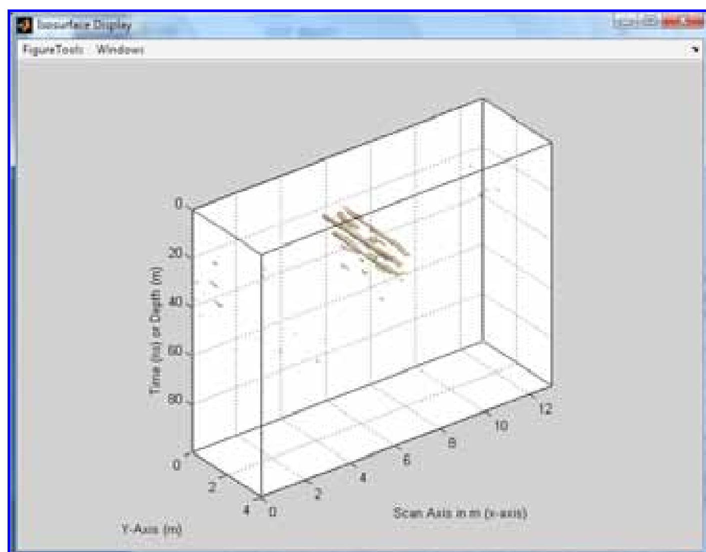


Figure 17. Equal signal amplitude display: Pipes buried at depths of 1.4–1.8 meters.

3-D Slice Displays

A *"Slice Display"* is an orthographic projection of the radargrams in the form of sections parallel to the scan-axis (x-axis), as in Figure 19. The slices are initially opaque. The display is controlled by the GUI of Figure 18 (*3-D Display Controls*), which is organized in panels as follows:

The *Y-slices* panel determines the number of slices displayed and their transparency. The number of slices is controlled via a slider and/or an editable box, both labeled *Display Y-slices*, according to their position with re-spect to the y-axis. By default, all Y-slices, i.e. all the profiles comprising the data volume are shown on startup, arranged from last to first. Translucence is enabled/ disabled via the *Translucence On/Off* box. The trans-parency may be changed via the *increase* (▲) or *decrease* (▼) push buttons. The method by which to introduce translucence in the display is credited to Conroy and Radzevicius (2003).

The Slice Display can be augmented with addition of X- and Z-slices, one of each at a time. The position of these slices can be controlled with the sliders and editable boxes of the *X, Z slices* panel. X- and Z- slices are not displayed on start-up, but may be introduced later, either by moving the respective sliders to the appropriate position, or by typing their position in meters, in the respective editable boxes. Figure 20 shows the same data as per Figure 19, but with increased transparency, an X-slice at 23m along the scan axis (where a buried wall was detected), and a Z-slice at 38ns along the traveltime axis, where there are intense reflections from a buried inter-face.

Color Saturation (contrast) can be varied with an appropriate slider. In combination with translucence, increas-ing the contrast allows many features to stand out clearly. The aspect ratio of the axes can be controlled as above, while the viewing angle may be changed with the *Azimuth* and *Elevation* sliders and editable boxes (*Viewer Position* panel).

An Example

As should already be apparent, matGPR particularly emphasizes on analysis and tries to include advanced and effective processing and interpretation methods to handle normal, as well as complicated data sets. In order to assert this point, and because no statement or description is good without examples, this presentation concludes with the analysis of a not-so-usual radargram.

The data was collected on a ridge (Mt Ktenias, altitude ~1600m, NE Peloponnesus, Greece), where high-rising wind-powered electricity generators were to be erected, as part of a geotechnical survey to investigate the conditions and consistency of the foundation

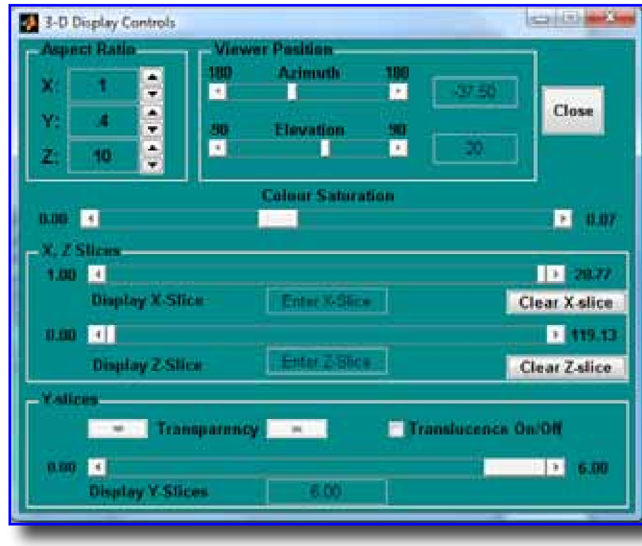


Figure 18. GUI to control 3-D slice presentations of GPR data volumes.

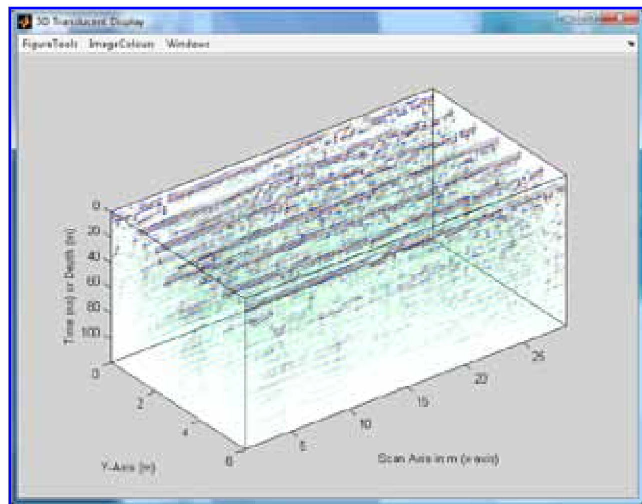


Figure 19. 3-D Slice Display with translucence.

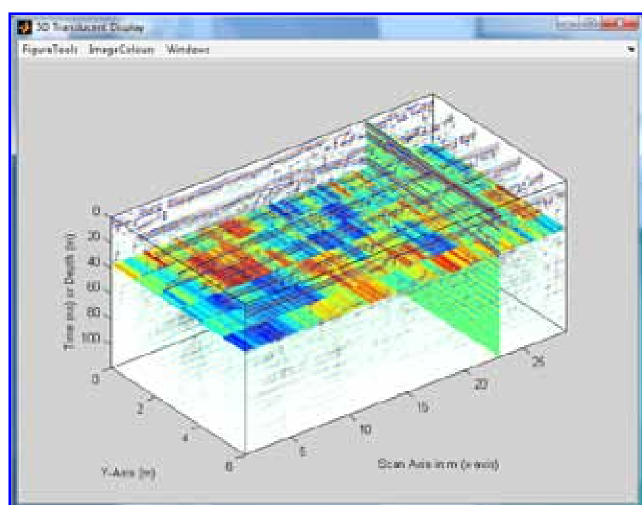


Figure 20. The data of Figure 19 with increased trans-parency, an X-slice and a Y-slice.

ground (e.g. to detect voids). The geological setting is shown in Figure 21. The ground comprises dipping, thin-plated limestone with intercalations of argillaceous material, intensely fragmented and karstified (see insets in Figure 21). As evident in the photograph, many cracks and voids are filled with lateritic soil with a considerable argillaceous component.

Figure 21. The geological setting of the Ktenias ridge. The inset pictures show the type of karstic voids and cracks abundant in the subsurface. Photos by courtesy of Mr Pavlos Sotiropoulos, Terramentor EEIG.

The raw data was collected with a Måla GPR system and 250MHz antenna. Figure 22 shows the example section after time-zero adjustment, global background removal and AGC with a 20ns Gaussian-tapered window. The later parts of the data traces, (after approx. 80 ns), are infested with apparently random noise which is amplified by the AGC and masks other useful reflections. In addition, is apparent that the data suffer from a considerable degree of ringing, presumably due moist, near surface thin argillaceous layer(s).

The random noise cannot be treated with spatial smoothing filters effectively, because the medium contains many distributed targets whose reflections will be smeared in the process. Figure 23 is the data after F-K, zone-pass filtering; the F-K filter was preferred because as is apparent in the F-K spectrum, there are strong, frequency-local, laterally propagating noise components, presumably due to arrivals from dipping or sub-vertical scattering surfaces (e.g. cracks); it is more efficient to handle such noise simultaneously in the F-K domain, that separately in the F- or K- domains.

Elimination of the random noise shows that the ringing is actually quite strong, certainly stronger than what it appeared to be, and that at places interferes with reflections from cracks and voids. Elsewhere, it appears to be absent, especially at places with a high density of reflection events, presumably due to the disturbance/ destruc-tion of the conductive layer(s) by the formation of cracks and voids. The uncertainty introduced by the interfe-rence significantly complicates interpretation.

In this case, the ringing shown in Figure 23 can be modeled by separating its τ-*p* domain contributions, as discussed in section *Tau-p Filter* above and Figure 10. The residual of this exercise are shown in Figure 24 and is apparently free of the ringing effect. Notably, the same result could be obtained with Karhunen-Loeve transformation; in this approach, a representative model of the ringing can be reconstructed using the first two principal components (N=2).

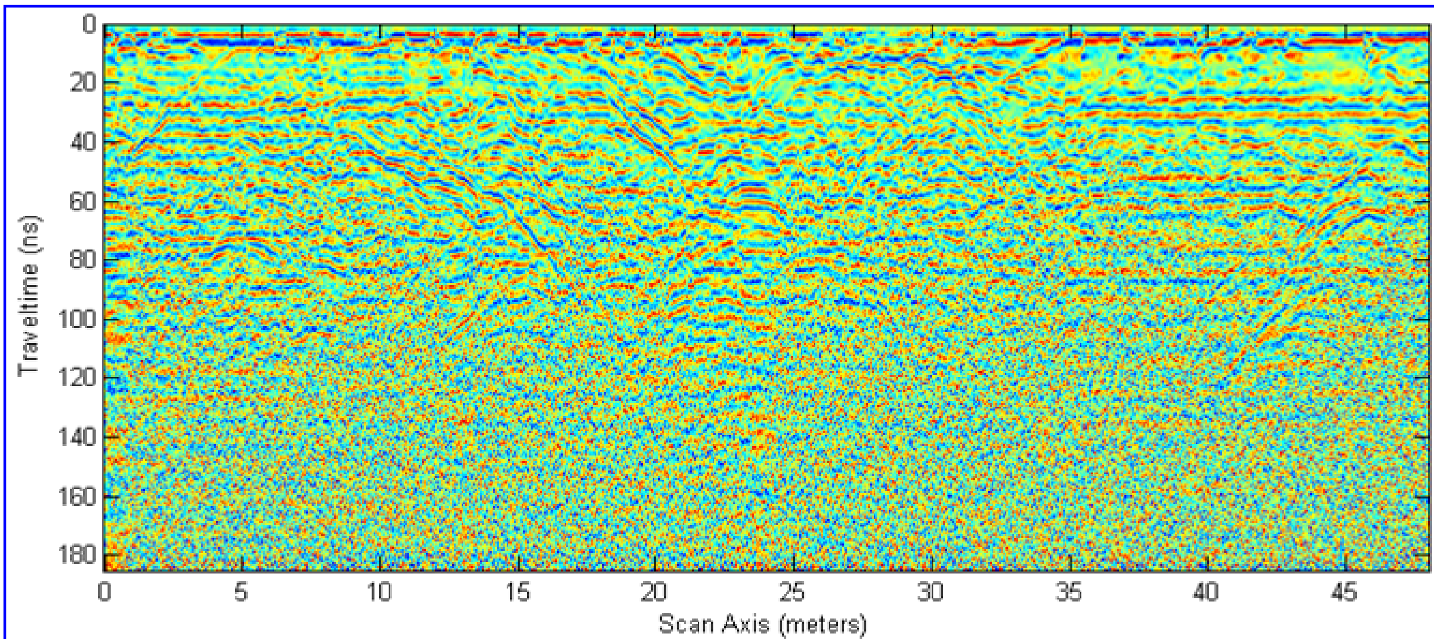


Figure 22. A GPR section collected above fragmented and karstified limestone at the location shown in Figure 21, after preprocessing (time-zero adjustment, background removal and amplification).

There are several diffraction hyperbolae in the section, to allow velocity analysis at different locations and depths; these can be seen more clearly in gray scale but are not included herein for brevity. The fitting process is not shown also for brevity, but the results indicate a small lateral velocity variation from ~0.085 m/ns to ~0.095 m/ns. It is not exactly clear why this should be, but it may be related to an inactive fault, which in Figure 21 can be seen just behind the radar operators, dipping from left to right between meters 22 and 32 of the section and bringing together strata with slightly different lithological characteristics. The karst and voids appear to have developed in association with this fault.

The resulting 2-D velocity model is simple enough, as to not justify the space required for its presentation. On the other hand, the application of split-step depth migration with this velocity model produces the result of Figure 25, in which the intricate structure of the foundation ground comes clearly in focus. It is almost straightforward to observe subvertical faults and fractures possibly filled with conductive (e.g. lateritic) material and at places intersecting, (e.g. around coordinates x=22.5, z=3.5), point-like reflections corresponding to small targets like (filled or empty) voids and a dipping interface (the bedding is clearly observable in Figure 21) approximately between coordinates (x=5, z=1) and (x=30, z=4.5).

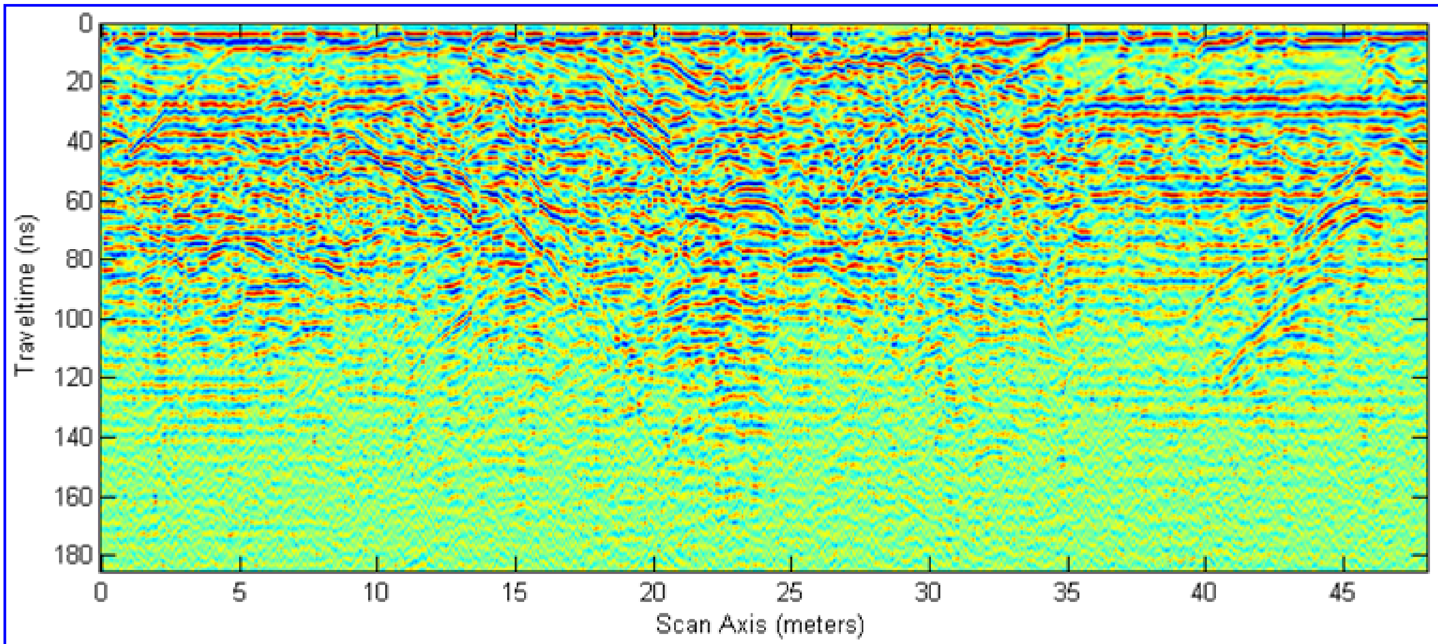


Figure 23. The GPR section of Figure 22, after eliminating random noise with zone-pass F-K filtering. See Figure 9 for a map of the F-K spectrum and the shape of the pass zone.

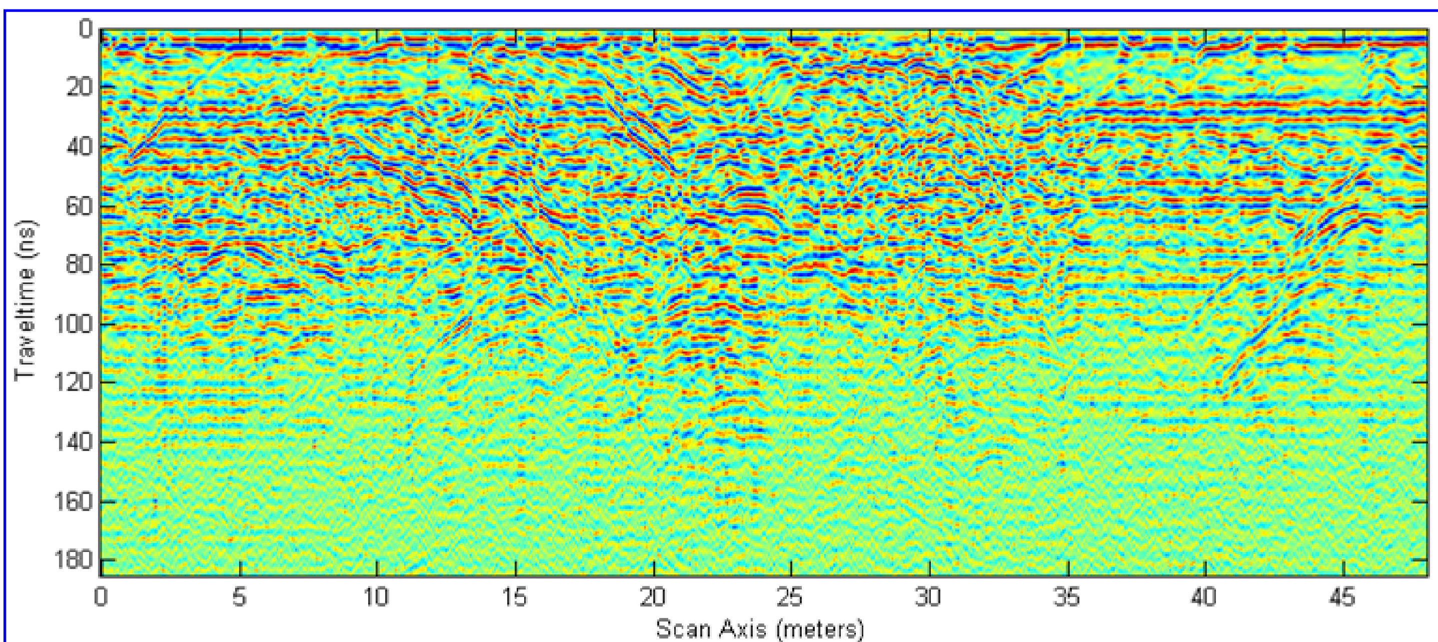


Figure 23. The GPR section of Figure 22, after eliminating random noise with zone-pass F-K filtering. See Figure 9 for a map of the F-K spectrum and the shape of the pass zone.

Epilogue

As demonstrated in the hitherto description, matGPR puts emphasis on data analysis and provides a relatively broad and functional range of analytical methods and procedures for the analysis of zero and single-offset GPR data. Its toolboxes enable the processing of "normal" and, more importantly, complicated and difficult data sets. For the same reason it can be used for education, albeit at a relatively advanced level (in Athens, we use a stand-alone educational version of Release 1). Moreover, special provisions were made to include in-house solutions for such algorithms and analysis techniques that are necessary but not supplied with the MATLAB core and can only be found in toolboxes. Thus, matGPR can be used by all those in possession of a basic MATLAB license.

On the downside, there are limits to backward compatibility, in as much as MATLAB evolves rapidly and continuously. matGPR is programmed to detect the MATLAB version and does not invoke functions

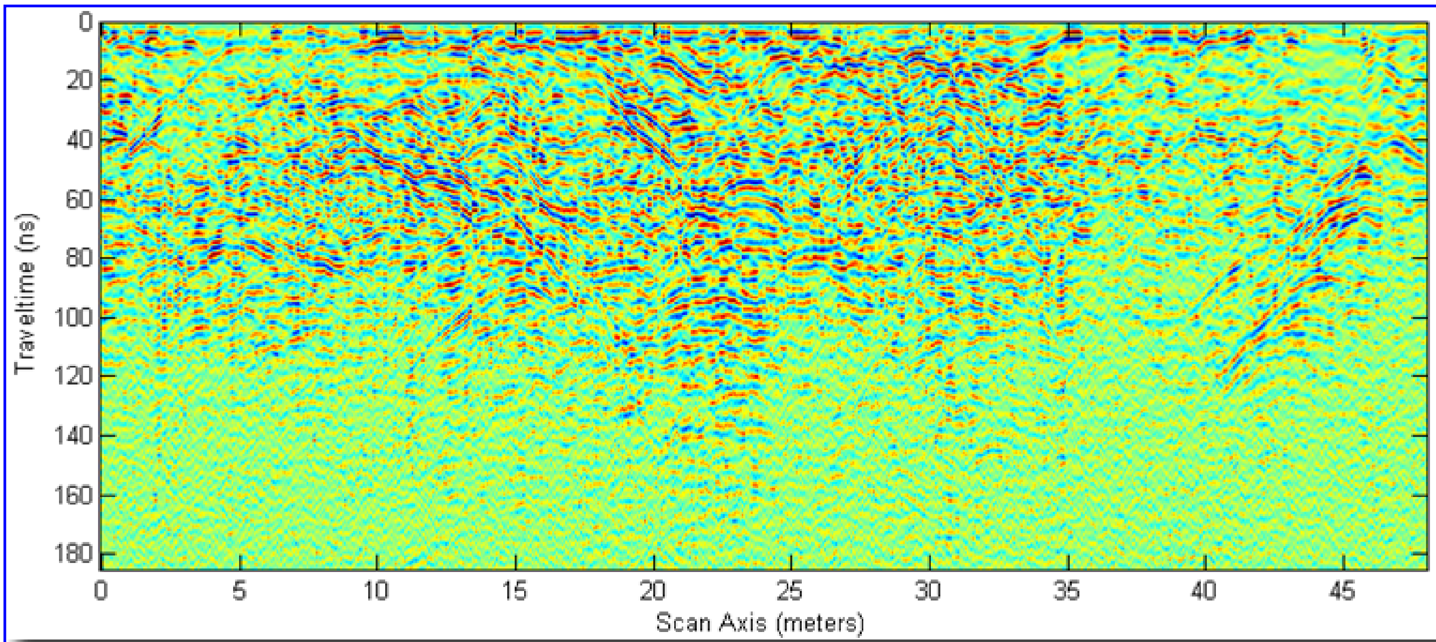


Figure 24. The GPR section of Figure 23 after removal of random noise with τ-p filtering. See Figure 10 for a map of the τ-p domain and the shape of the pass zone.

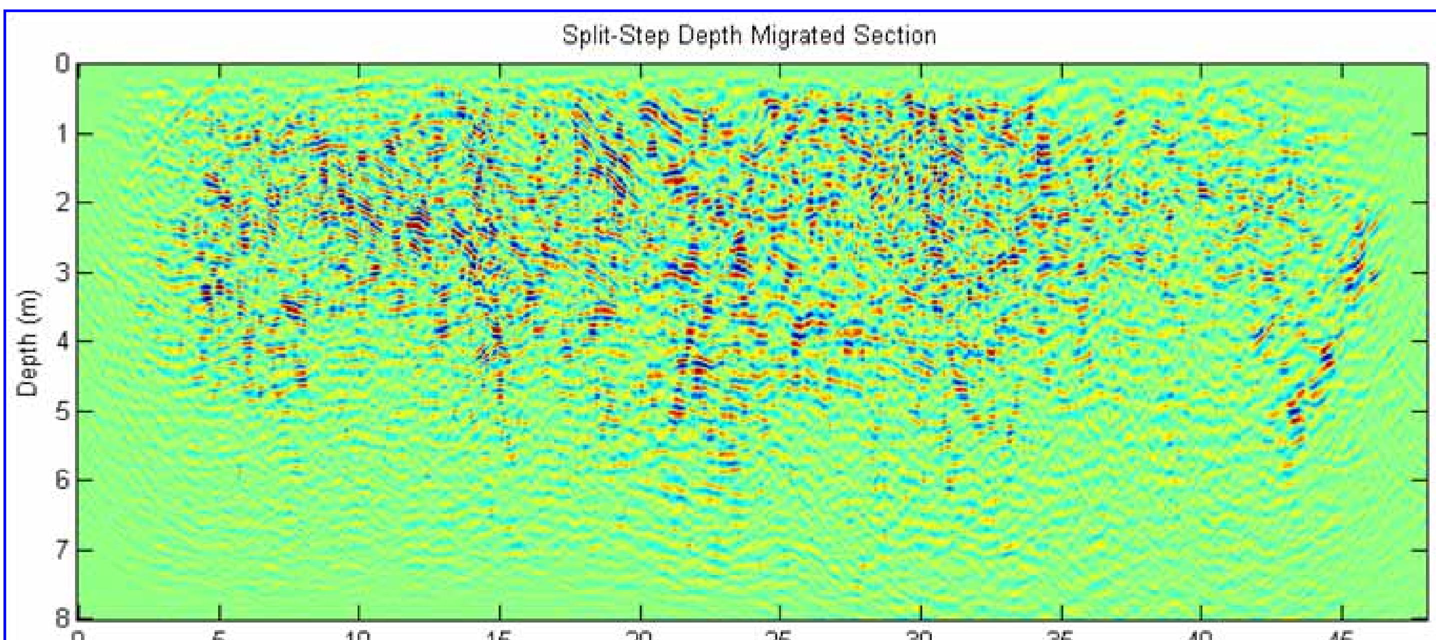


Figure 25. The GPR section of Figure 24 after imaging with 2-D split-step depth migration.

and procedures from a specific version, but executes alternative in-house solutions. The point of no return, however, has to do with the implementation of data constructs and procedures like *structures* and *cell arrays*, *function handle callbacks* etc. Thus, MATLAB V4 is *altogether out* of the picture. Also note that matGPR has never been tested with MATLAB V5.x and is not expected to work to anyone's satisfaction. It will cooperate with MATLAB V6.5, but probably not seamlessly. It should, however, cooperate seamlessly with MATLAB V7.1 – 7.3 and is fully functional with V7.4 and above.

At the present stage of development matGPR has a rather broad scope of application and is also versatile in that it is expandable and customizable to the needs of its users, provided of course they have MATLAB programming skills. Nevertheless, one can think a multitude of analysis tools that can be included in future releases. The author hopes that matGPR has the potential to grow and expand over time, welcoming contributions from other researchers in the spirit of the GNU project. At present, matGPR can be obtained from *http://users.uoa.gr/~atzanis/matgpr/matgpr.html*.

Acknowledgments

The author acknowledges limited support by the "Kapodistrias Programme" of the Research Secretariat, National and Kapodistrian University of Athens. Limited support was also provided by the European Social Fund and Greek National Resources through program EPEAEK II – PYTHAGORAS II, "Support for Research Groups in Universities". The example data from Ktenias Ridge and the photographs in Figure 21 are courtesy of Mr Pavlos Sotiropoulos, Terramentor EEIG, Athens, Greece (*http://www.terramentor.com*).

References

Bano, M., 1996. Constant dielectric losses of ground-penetrating radar waves, Geophysical Journal Int., 124, 279-288.

Bitri, A. and Grandjean, G., 1998. Frequency - wavenumber modelling and migration of 2D GPR data in moderately heterogeneous dispersive media, Geophysical Prospecting, 46, 287-301.

Canales, L. L., 1984, Random noise reduction: 54th Annual Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, Session:S10.1.

Claerbout, J., 1996, Imaging the Earth's Interior, Network Distribution Version, pp. 50-57 and 222-223; http://sepwww.stanford.edu/sep/prof/index.html.

Conroy, J. P. and Radzevicius, S. J., 2003. Compact MATLAB code for displaying 3D GPR data with translu-cence, Computers and Geosciences, 29/5, 679-681.

Crochiere, R and Rabiner, L. R., 1983. Multirate Digital Signal Processing, Englewood Cliffs, NJ: Prentice-Hall, Inc.

Fukunaga, K., 1990, "Introduction to Statistical Recognition", Academic Press.

Gazdag, J., 1978. Wave equation migration with the phase-shift method, Geophysics, 43, 1342-1351.

Gazdag, J. and Sguazzero, P., 1984. Migration of seismic data by phase-shift plus interpolation, Geophysics, 49, 124-131.

Grandjean, G. and Durand, H., 1999. Radar Unix: a complete package for GPR data processing, Computers & Geosciences, 25 141-149.

Gulunay, N., 1986, FX deconvolution and complex Wiener prediction filter: 56th Annual Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, Session:POS2.10.

Irving, J. and Knight, R., 2006. Numerical modeling of ground-penetrating radar in 2-D using MATLAB, Computers & Geosciences, 32, 1247–1258.

Karhunen, K., 1946, “Zur Spektraltheorie Stochastischer Prozesse”, Ann. Acad. Sci. Fennicae, 372.

Loeve, M.M., 1955, “Probability Theory”, Princeton, N.J.: VanNostrand.

Lucius, J.E. and Powers, M.H., 2002. GPR Data Processing Computer Software for the PC, USGS Open-File Report 02-166.

Sacchi, M.D., 1997. Re-weighting strategies in seismic deconvolution, Geophysical Journal International, 129, 651-656.

Sena, A.R., Stoffa, P.L. and Sen, M. K., 2003. Split Step Fourier Migration of Ground Penetrating Radar Data: 73th Annual Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 1023-1026.

Smith, J. O. and Gossett, P., 1984. A flexible sampling-rate conversion method in “Proceedings of the International Conference on Acoustics, Speech, and Signal Processing” ICASSP-84, Volume II, pp. 19.4.1-19.4.2, New York: IEEE Press. Also, see expanded tutorial and associated free software at the Digital Audio Resampling Home Page: http://www-ccrma.stanford.edu/~jos/resample/

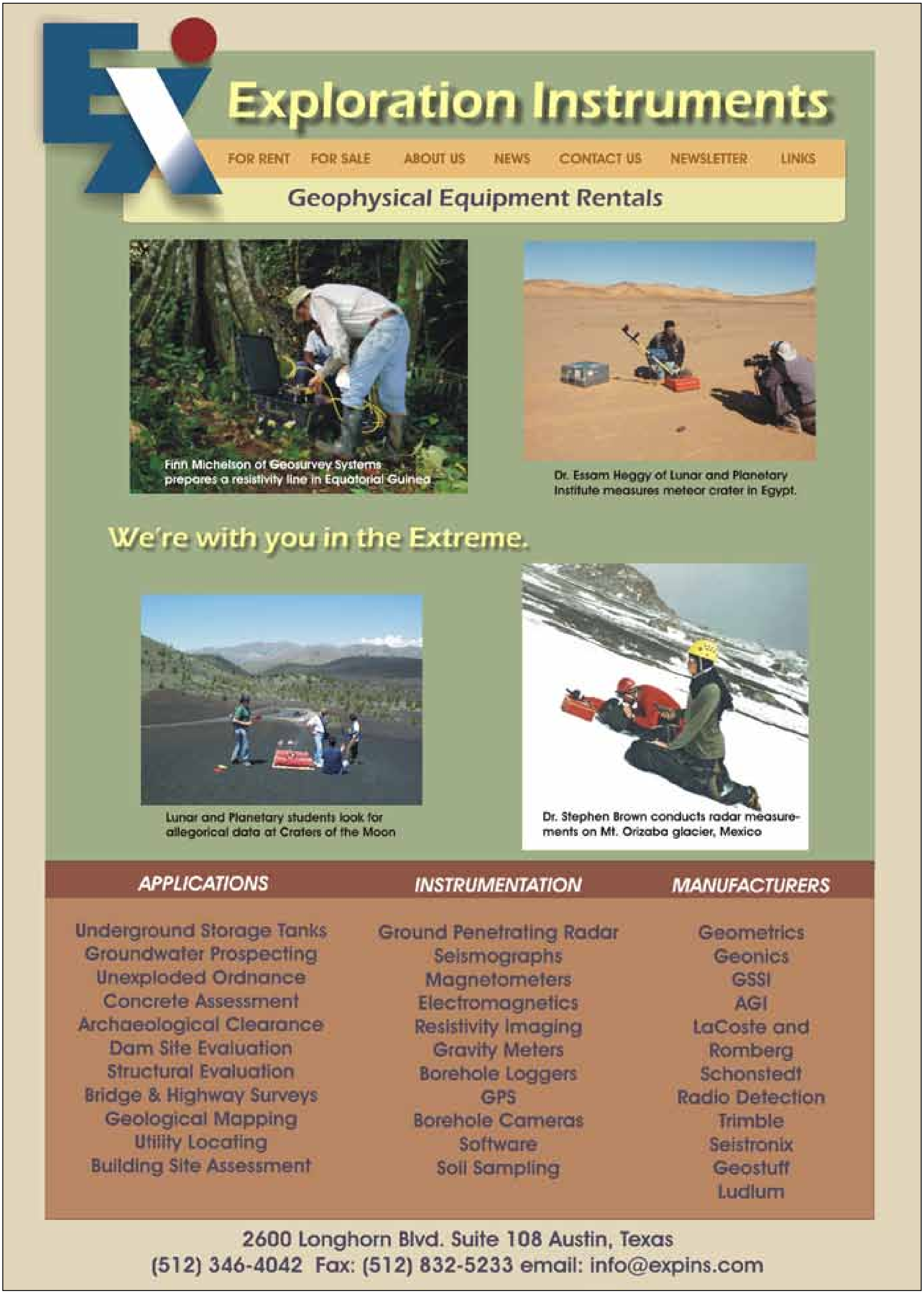
Stoffa, P.L., Fokkema, J.T., de Luna Freire, R.M. and Kessinger, W.P., 1990. Split-step Fourier migration, Geophysics, 55, 410-421.

Stolt, R.H., 1978. Migration by Fourier Transform, Geophysics, 43, 23-48.

The R.T. Clark Companies Inc.

Seismographs
GPR
Geophones
Mags
Cables
Resistivity
Loggers
EM & More!!!

Web: rtclark.com Email: rtclark@rtclark.com
Tele: 405-751-9696 Fax: 405-751-6711
P.O.Box 20957, Oklahoma City, Oklahoma 73157 USA

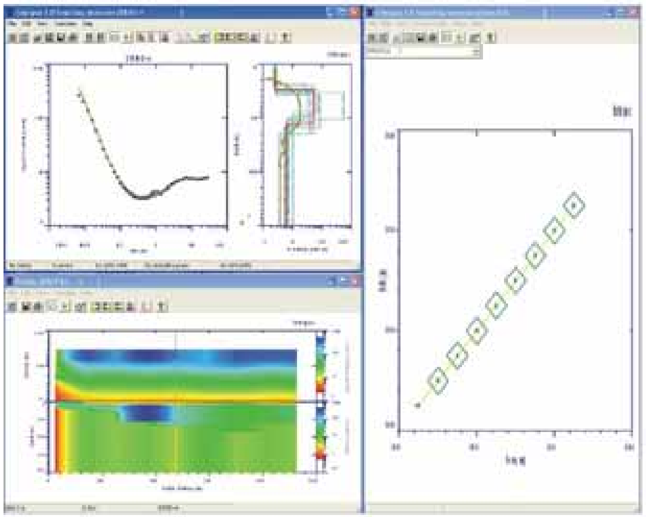

Exploration Instruments
FOR RENT
FOR SALE
ABOUT US
NEWS
CONTACT US
NEWSLETTER
LINKS
Geophysical Equipment Rentals
Finn Michelson of Geosurvey Systems prepares a resistivity line in Equatorial Guinea
Dr. Essam Heggy of Lunar and Planetary Institute measures meteor crater in Egypt.
We're with you in the Extreme.
Lunar and Planetary students look for allegorical data at Craters of the Moon
Dr. Stephen Brown conducts radar measurements on Mt. Orizaba glacier, Mexico
APPLICATIONS
Underground Storage Tanks
Groundwater Prospecting
Unexploded Ordnance
Concrete Assessment
Archaeological Clearance
Dam Site Evaluation
Structural Evaluation
Bridge & Highway Surveys
Geological Mapping
Utility Locating
Building Site Assessment
INSTRUMENTATION
Ground Penetrating Radar
Seismographs
Magnetometers
Electromagnetics
Resistivity Imaging
Gravity Meters
Borehole Loggers
GPS
Borehole Cameras
Software
Soil Sampling
MANUFACTURERS
Geometrics
Geonics
GSSI
AGI
LaCoste and Romberg
Schonstedt
Radio Detection
Trimble
Seistronix
Geostuff
Ludlum
2600 Longhorn Blvd. Suite 108 Austin, Texas
(512) 346-4042 Fax: (512) 832-5233 email: info@expins.com

Interpex Software

IX1D version 3

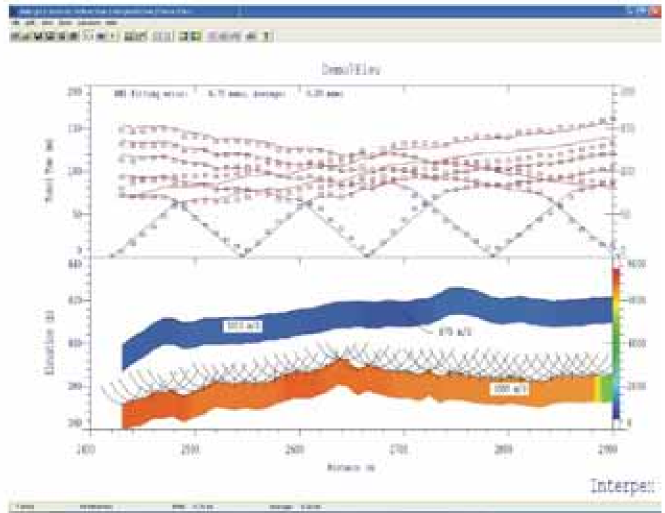
available with or without TEM option

1D Sounding Interpretation with profile support
DC, IP, MT, FEM, EM Conductivity (TEM optional)



IXRefraX

Simply the fastest and best Seismic Refraction Processing and Interpretation Software using the Generalized Reciprocal Method



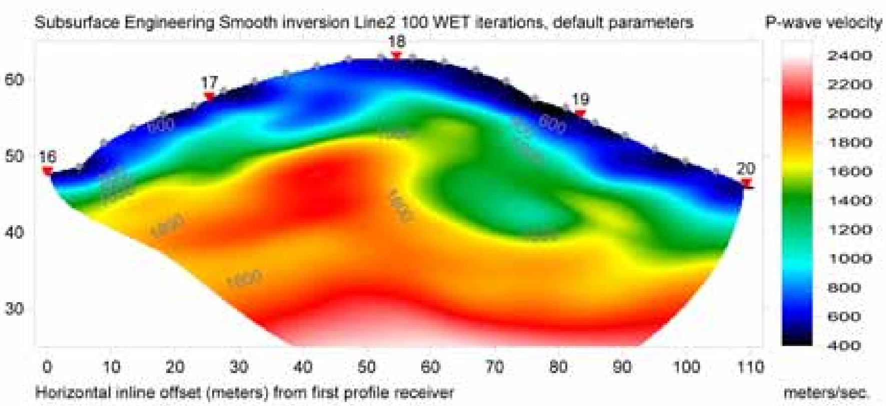
P.O. Box 839
Golden CO 80402

Tel (303) 278 9124
Fax (303) 278 4007

www.interpex.com
info@interpex.com

INTERPEX

INTELLIGENT RESOURCES INC. offers **RAYFRACT®** Seismic Refraction & Crosshole Tomography software : velocity structure imaging for civil engineering and exploration



Intelligent Resources Inc.
142-757 West Hastings Street
Vancouver B.C. V6C 1A1
Canada

Phone +1 604 782-9845
Fax +1 604 408-8678
Web http://rayfract.com
E-mail sales@rayfract.com

150 full licenses sold.

Our Rayfract® traveltime tomography software models refraction, transmission and diffraction of seismic waves. Just define 2D profile geometry, import or pick first breaks then obtain optimal interpretations automatically. Supports extreme topography and strong lateral velocity variation. Handles velocity inversions. Now allows true 2D Smooth inversion of crosshole surveys, with constant-velocity initial model. Includes conventional Plus-Minus, Wavefront methods. Allows import of SEG-2, ABEM Terraloc Mark III, Bison 9000 Series binary trace data. Can read many third-party ASCII file formats with first breaks and recording geometry. The price of an end user license remains unchanged at US $ 2,200.00 including one year of support. We offer a price reduction of 20% to academic and non-profit organizations. Send us a test profile for free interpretation. Visit our web site for our updated PDF help, manual, free trial, tutorials etc. You may rent our software. Rentals can be renewed or upgraded. Resellers are welcome.

Copyright © 1996-2009 Intelligent Resources Inc. RAYFRACT is a registered trademark of Intelligent Resources Inc. Canadian Business Number 86680 1236. British Columbia Incorporation Certificate No. 605136. Requires Golden Software's Surfer for plotting.

Micro-resistivity and GPR surveys for locating thermal lines in limestone bedrock cuts

Mustafa Saribudak, Principal Geophysicist-Geologist, Environmental Geophysics Associates, Austin, TX(ega@pdq.net).

Site Background

An industrial client asked us to locate thermal lines in the backyard of his main building where he wanted to construct an additional facility on 12 piers (Figure 1). He wanted to make sure that the piers did not break the thermal lines during the construction. Thermal lines come out under the main building and were installed into bedrock cuts (weathered limestone), under the few feet of soil, and into the bedrock as deep as 200 feet. Locations of thermal lines under the building and in the backyard were not known, and thus we were contracted to locate them.

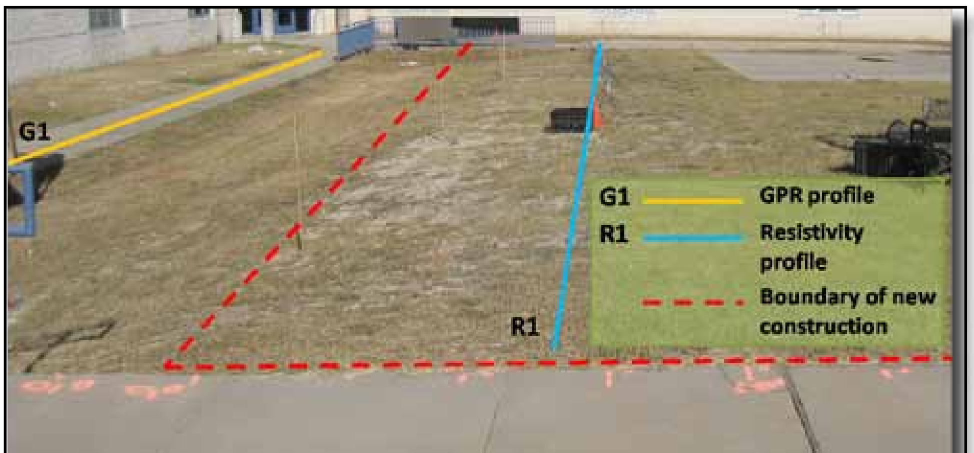


Figure 1. A picture showing the study area. Note the locations of GPR and resistivity profiles, and the new construction site.

We really did not know in detail what the thermal lines were all about until we arrived at the site. We accepted the scope of the work as locating utility lines and brought with us 6 geophysical instruments (conductivity - EM31, EM61, magnetometer, ground penetrating radar, and resistivity). After talking to the client, we learned the following: thermal lines, which are plastic pipes a quarter of an inch in diameter, are part of a geothermal heat pump which is a central heating or cooling system that pumps heat to or from the ground. It uses the earth as a heat source (in the winter) or a heat sink (in the summer). This design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems.

Geophysical Methods

After getting more information about the thermal lines, and inspecting the site, we chose to perform only GPR and resistivity surveys. Resistivity imaging is a survey technique that aims to map of the electrical properties of the subsurface by passing an electrical current between electrodes and measuring the associated voltages. This technique has been widely used in mapping contaminant plumes, karst features (voids), and subsurface structures, such as faults and fractures. In this study, the Advanced Geosciences, Inc. (AGI) Super R1 Sting/Swift resistivity meter with the dipole-dipole resistivity technique is used. This technique is more sensitive to horizontal changes in the subsurface, and provides a 2-D electrical image of the near-surface geology. Electrode spacing was held to 2 feet along all profiles and a roll-along survey method was employed. The depth of the investigation was about 13 feet.

The 400 MHz antenna (shallow mode) was used with a cart system to collect GPR data. GPR is the general term applied to techniques that employ radio waves in the 1 to 1000 megaHertz (MHz) frequency range to map near-surface structures and man-made features. Depth penetration of the radio waves is limited by the antenna chosen and the conductivity of the soil. The ability of a GPR system to work successfully depends upon two electrical properties of the subsurface, electrical conductivity and relative dielectric permittivity (i.e. dielectric constant). The value of dielectric constant ranges between 1 (for air) and 81 (for water). The dielectric constant for sandy clayey soils varies between 10 and 15. A dielectric constant of 12 was chosen for the study area, and the depth exploration with the GPR unit was about 6 feet. Thus, differences in the dielectric constant of subsurface soils along distinct boundaries, such as voids (bedrock cuts), can cause highly significant reflections in the radar signal, which are recorded and displayed by the system. In summary, GPR radar reflections occur when GPR waves encounter a change in velocity due to dielectric contrast. The bigger the change the more signal is reflected (Geophysical Survey System, Inc. GPR SIR-2000 Manual, 2000).

Geophysical Survey Design and Results

First we conducted pilot GPR surveys along the concrete walk ways and across the new construction area. The GPR data collected along the concrete walk way (line G1) showed four distinct and similar anomalies 2 feet long along the profile, as indicated by letters A, B, C and D (Figure 2). These anomalies are about 20 feet apart from each other.

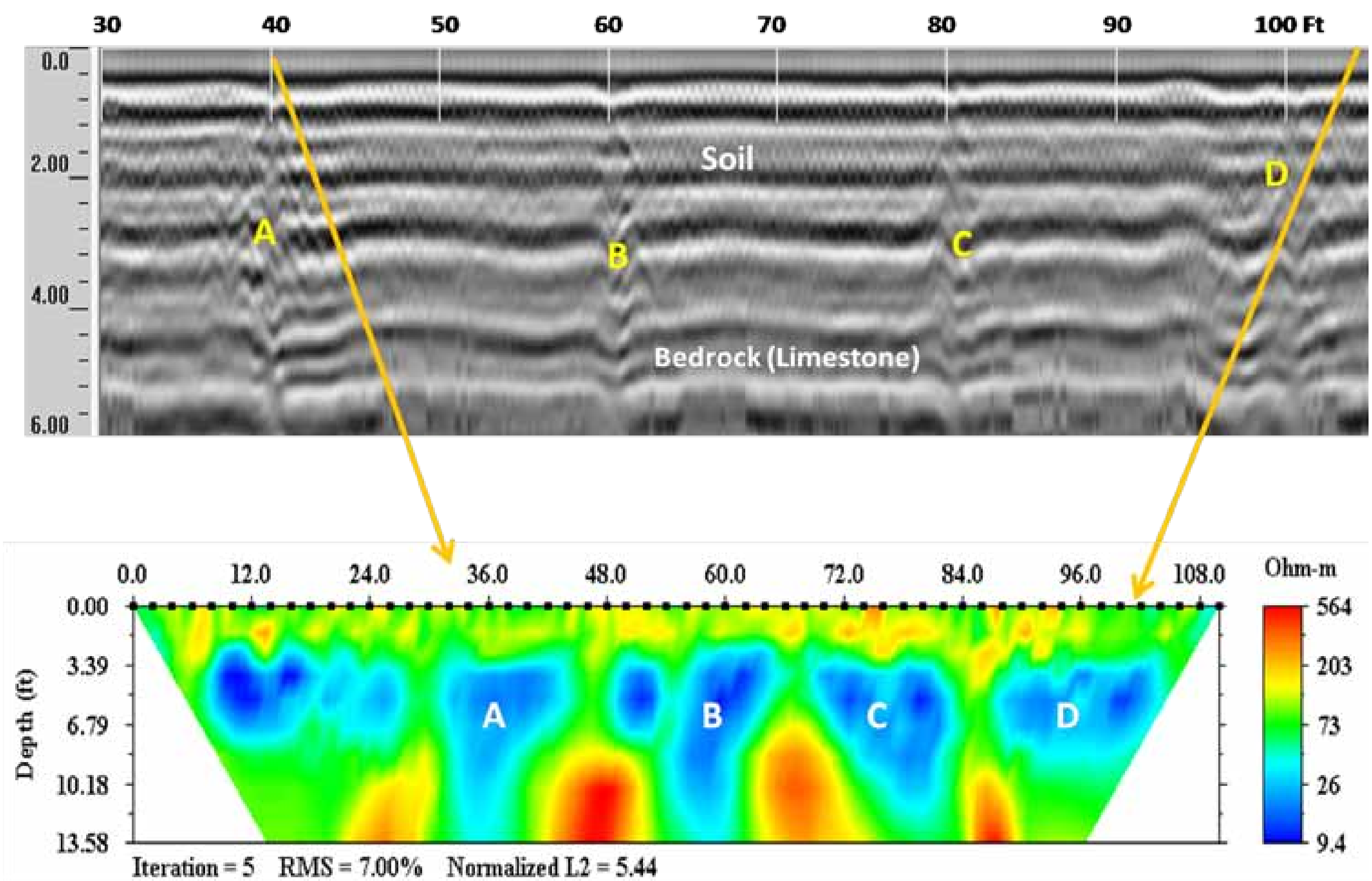
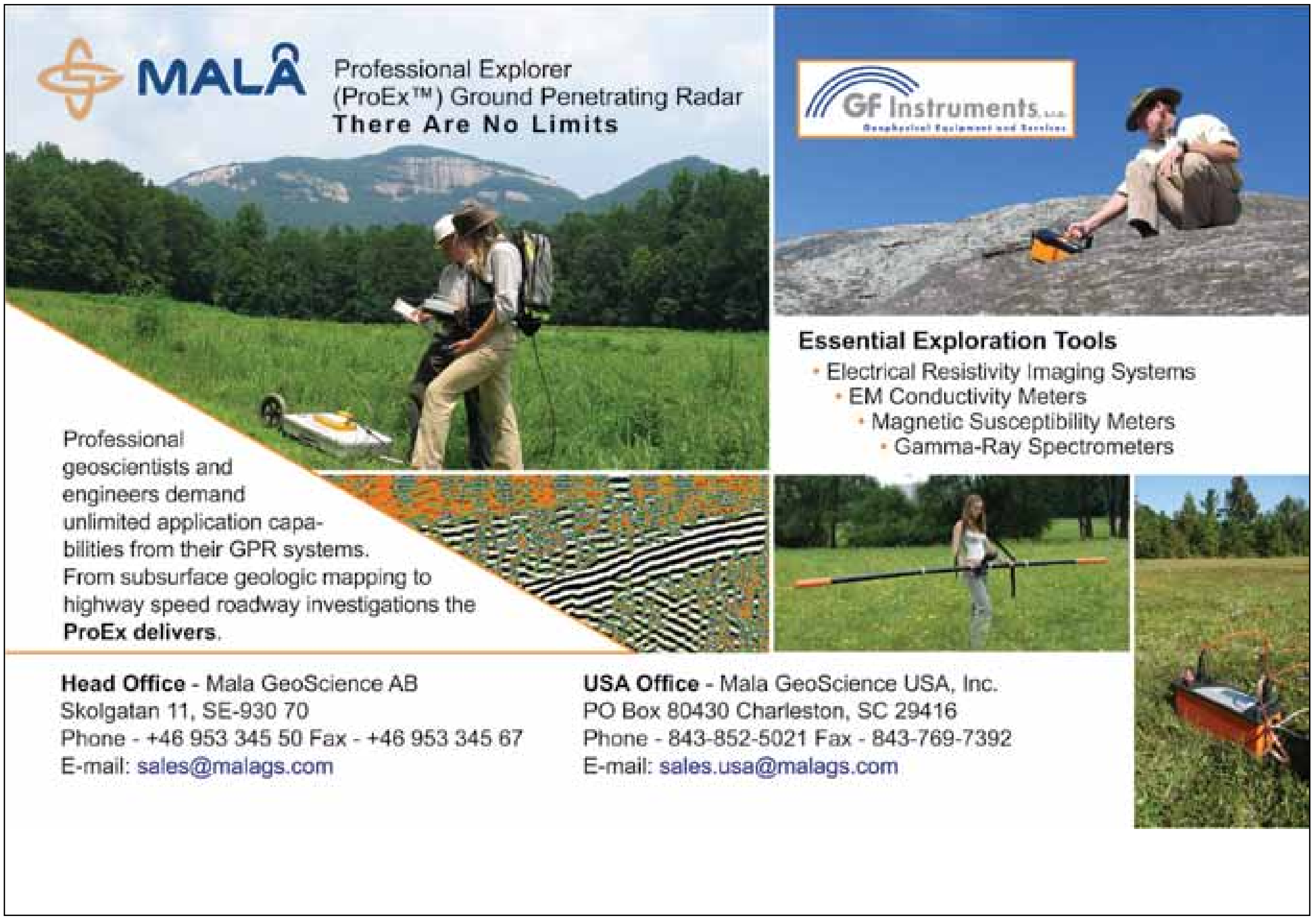


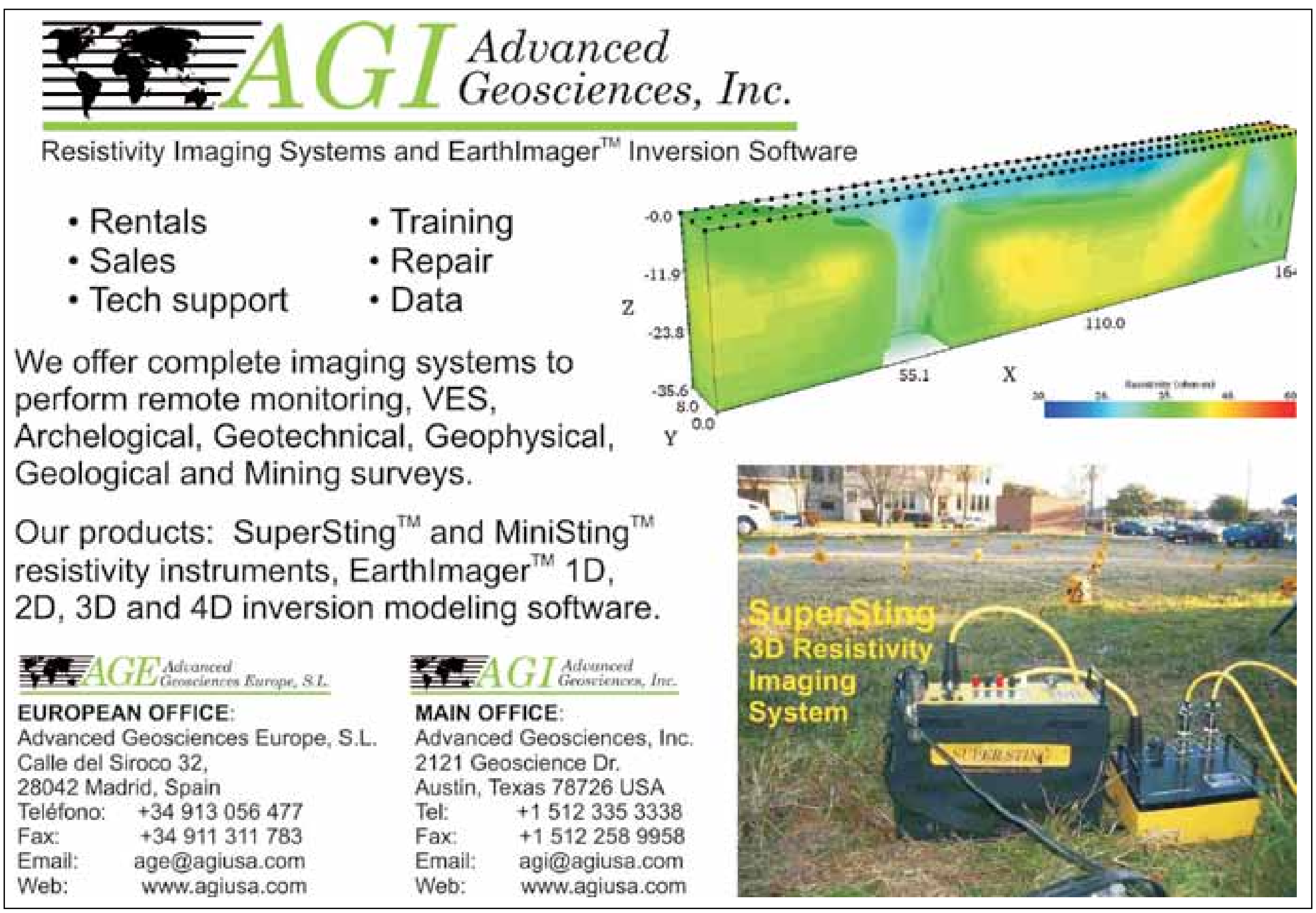
Figure 2. GPR (above) and resistivity (below) data along profiles G1 and R1. The distance between the two profiles is about 50 feet. The GPR data is taken on and along the concrete walkway whereas the resistivity data taken within the planned construction site (see Figure 1 for location).

We further investigated these anomalies with a roll-along resistivity survey. We took the electrode spacing 2 feet because of the length of the GPR anomalies were about 2 feet (Figure 2). The resistivity profile (line R1) located 50 feet away from the GPR profile also indicated very unique low resistivity anomalies (blue in color). These anomalies are also shown with letters A, B, C and D, and correlate very well with the GPR anomalies. The shape of the low resistivity anomalies suggests that these locations were disturbed and excavated. It should be noted that GPR surveys along the resistivity profile did not show any anomalies due to the absence of dielectric constant between the undisturbed and the disturbed soil.

We saw the results of our work while we were at the site (Figure 3): An excavator dug a trench along the resistivity profile and located the bedrock cuts of A and B. We later learned that the rest of the anomalies were also found, and the construction was completed without any problem. And we felt like another mission was completed to the satisfaction of our client and ourselves!

Figure 3. A trench showing the bedrock cuts A and B determined by the resistivity data. The rest of the bedrock cuts (C and D) was located later. The GPR data along this line did not show any anomalies. However, locations of these bedrock cuts were correlated well with the GPR data taken along the concrete walk way, which is located to the left.


MALÅ
Professional Explorer
(ProEx™) Ground Penetrating Radar
There Are No Limits
Professional geoscientists and engineers demand unlimited application capabilities from their GPR systems. From subsurface geologic mapping to highway speed roadway investigations the ProEx delivers.
Head Office - Mala GeoScience AB
Skolgatan 11, SE-930 70
Phone - +46 953 345 50 Fax - +46 953 345 67
E-mail: sales@malags.com
USA Office - Mala GeoScience USA, Inc.
PO Box 80430 Charleston, SC 29416
Phone - 843-852-5021 Fax - 843-769-7392
E-mail: sales.usa@malags.com
GF Instruments
Essential Exploration Tools
• Electrical Resistivity Imaging Systems
• EM Conductivity Meters
• Magnetic Susceptibility Meters
• Gamma-Ray Spectrometers


AGI Advanced Geosciences, Inc.
Resistivity Imaging Systems and EarthImager™ Inversion Software
• Rentals
• Sales
• Tech support
• Training
• Repair
• Data
We offer complete imaging systems to perform remote monitoring, VES, Archelogical, Geotechnical, Geophysical, Geological and Mining surveys.
Our products: SuperSting™ and MiniSting™ resistivity instruments, EarthImager™ 1D, 2D, 3D and 4D inversion modeling software.
AGE Advanced Geosciences Europe, S.L.
EUROPEAN OFFICE:
Advanced Geosciences Europe, S.L.
Calle del Siroco 32,
28042 Madrid, Spain
Teléfono: +34 913 056 477
Fax: +34 911 311 783
Email: age@agiusa.com
Web: www.agiusa.com
AGI Advanced Geosciences, Inc.
MAIN OFFICE:
Advanced Geosciences, Inc.
2121 Geoscience Dr.
Austin, Texas 78726 USA
Tel: +1 512 335 3338
Fax: +1 512 258 9958
Email: agi@agiusa.com
Web: www.agiusa.com
-0.0
-11.9
-23.8
-35.6
Z
8.0
0.0
Y
55.1
X
110.0
SuperSting
3D Resistivity
Imaging
System

Object based reconstruction of resistivity data using artificial neural networks

Mehrez Elwaseif, Department of Earth and Environmental Sciences, Rutgers-The State University, Newark, NJ (mehrez@andromeda.rutgers.edu).

Introduction

Resistivity imaging is a popular geophysical technique frequently applied to predict the location of subsurface structures and objects having a detectable electrical resistivity contrast relative to the host medium. The method is routinely employed to obtain an image of subsurface targets in the absence of a priori information on the geometry and distribution of those targets. Under such conditions, the smoothness constraint inversion is utilized to produce smooth resistivity images. This regularization constraint is conceptually appropriate, when the objective is to predict changes in resistivity due to variations in moisture and/or salinity across space and time. However, when the objective is to predict targets that are characterized by sharp resistivity contrasts (e.g., sinkholes, tunnels, voids), the smoothness constraint is conceptually inappropriate as our priori expectation is that such targets represent a sharp change in resistivity across some unknown boundary location. In addition to that, it is difficult to assess the true resistivity and quantify the geometries (defined here as width, height and depth of burial) of these targets from those resistivity models.

Several studies have been conducted to improve the reconstruction of targets characterized by sharp boundaries. Slater and Binley (2006) describe a modification of the smoothness constraint to accommodate sharp boundaries whereby a 'disconnect' in the smoothing is defined along the boundary of an object. However, this method requires that the boundary of the target be known a priori, and the inversion then solves for a smoothly varying model structure across the host medium and within the disconnected target. Blaschek et al. (2008) describe an inversion approach that incorporates a focused regularization scheme based on minimum gradient support that attempts to incorporate sharp boundaries without a priori information whilst still allowing for smooth model structure within the target and away from it. However, the main drawback of this approach is that a suitable smoothness parameter depending on a priori information has to be determined by the user.

Here, the author propose the use of digital processing procedures and artificial neural networks for improving the location of cavities from an initial smoothness-constrained inversion without the need to incorporating subsurface priori information. the approach combines: (1) an initial inversion using the standard smoothness constraint and a homogeneous starting model, (2) an image processing technique known as the watershed algorithm for predicting the geometries of those targets from the smooth inversion result, and (3) feeding the output geometries from the watershed algorithm, the mean resistivity value of the host medium, and finally the resistivity value at the centre of resistivity anomaly (the latter two parameters are picked directly from the smooth resistivity model generated after the first step) into a neural network model to obtain an improved estimate of the target resistivity, in addition to its geometry. The approach was applied on synthetic and field data. The synthetic studies include a single resistive cavity model and a conductive target embedded in a resistive medium. In the case of the single cavity models, the combined error is 10%, whereas it is 8 % for the conductive target. The method is also applied to data collected over a bridge in NJ.

Methodology

Digital image processing techniques can be used to predict the location of sharp edges based on mathematical properties of the image parameter space. The watershed by simulated immersion is a powerful tool for segmenting a given image into regions with distinctive boundaries (Roueff et al. (2004); Barraud (2006)). The approach assumes that the edges in the image predicted from the watershed algorithm are consistent with the edges of some unknown resistivity model characterized by sharp boundaries for which we have a smooth image. In this study the watershed method (as described in Elwaseif and Slater, in press) was applied on smooth resistivity images to predict the edges of features manifest in resistivity inversion results as smooth boundaries.

Artificial Neural Networks (ANN) is based on a parallel computational system that attempts to simulate the interconnected system of neurons in the human brain (Smith 1993). The basic structure of an ANN consists of an input layer, which has a number of neurons equal to the number of input parameters (in this case, the predicted geometries from the watershed, the average host medium resistivity and the target' central resistivity value), and an output layer consists of neurons forming the output parameters (e.g., target's geometry and resistivity). The number of layers forming the ANN (i.e. complexity) can be increased by including hidden layers between the input and output layers. All the layers are connected via connection weights. During the learning (or training) stage, the output from the hidden layers is compared with the desired output and the connection weights are updated until a good approximation between the input and the desired output is achieved. After completing the training stage (i.e., the lowest RMS error between the input and desired output is achieved), the ANN can predict the desired output for a given input quickly and accurately (Smith 1993).

Synthetic models

The synthetic apparent resistivity pseudosections for a single cavity and a conductive target were calculated using R2 code (Binley and Kemna, 2005). To simulate real data collected in the field, the synthetic datasets were contaminated with 3% Gaussian noise. The conductive and resistive cavity models were buried at 1.25 m depth, having a width and length of 3 m. The resistive cavity was buried in 10 Ohm m host medium and has a resistivity of 100 Ohm m, whereas the conductive target was buried in 100 Ohm m medium and has a resistivity of 10 Ohm m. Figures (1a & 2a) show the synthetic conductive and resistive models. The synthetic data were inverted using the robust inversion and a homogeneous starting model (as usually happens in practice). The robust inversion is more appropriate for imaging targets characterized by sharp boundaries, since it results in sharper boundaries between regions with different resistivity values, although resistivity values vary less within each region (e.g., Loke et al., 2003; Elwaseif and Slater, in press). The watershed algorithm is applied to the resultant images from inversion to predict the geometries of the resistivity anomalies. The output geometries from the watershed algorithms along with the average

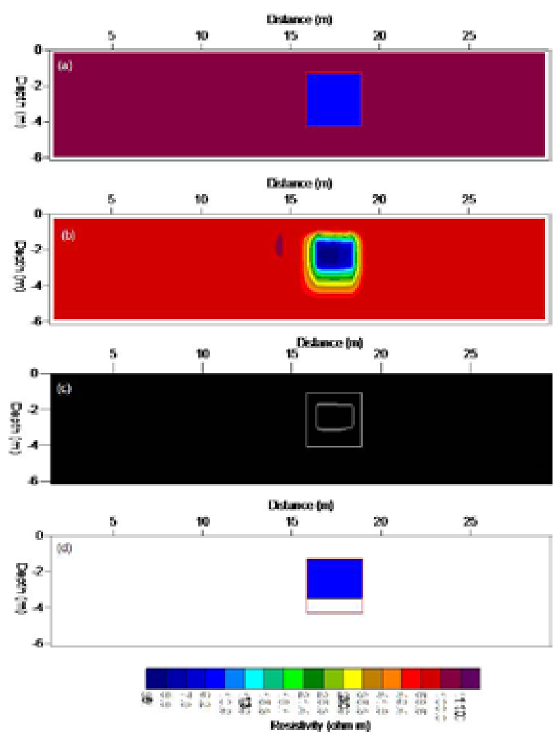


Figure 1. Results of the reconstruction process of the conductive anomaly (a) subsurface model (b) smooth section (c) detected boundary based on a (d) neural networks section (box denote true target outline).

host medium resistivity and the central target' resistivities for the two synthetic models were used as an input to the neural networks.

Results

The results of applying the robust inversion on the conductive and resistive cavity are presented in Figures 2b and 3b, respectively. As expected, the models are smooth, with sharper boundaries and less resistivity variation within the model space represented by the targets. Figures (1c & 2c) show the results of applying the watershed method on the robust images for both models. The method has underestimated the boundary of the conductive target, while it overestimates the boundary of the resistive target. The results of applying the ANN on both models are shown in figures (1d & 2d) and summarized in Table 1. The ANN predicted the resistivity and boundary of the conductive target with an average error of 10 %, whereas the average error for the resistive target was 8%.

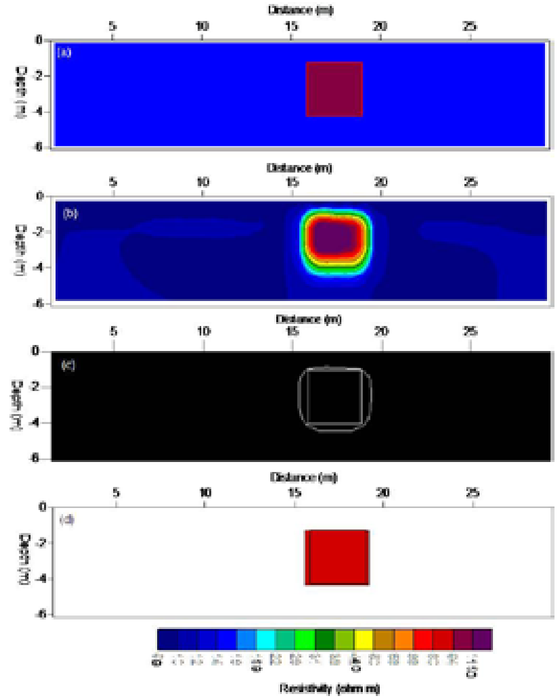


Figure 2. Results of the reconstruction process of the resistive anomaly (a) subsurface model (b) smooth section (c) detected boundary based on a (d) neural networks section (box denote true target outline).

In order to illustrate this approach on real datasets, the ANN was applied on datasets acquired over the bridge on Figure (3a). The depth and dimension of the void underneath the bridge were accurately measured. A 2D dipole-dipole array with 1 m electrode spacing and 6 depth levels was acquired using a Supersting (AGI Instruments, USA) automatic resistivity system, providing 864 measurements, with a modeled maximum investigation depth of about 6 m. The inversion followed the same processing steps as performed on the synthetic datasets. Figure (3b) shows the inverted resistivity profile using the robust inversion and a homogeneous starting model. The section displays a wide range of resistivity values. The anomalous zone located at surface area of 11 to 13 m and at a depth of about 1 m is believed to be related to the void underneath the bridge. The watershed algorithm wasn't able to predict the void accurately as shown in Figure (3c). On the other hand, the ANN provided a more reliable resistivity value for the void (176300 Ohm m) and predicted its geometry with an average error of 16%.

Resistivity Models	True resistivity (Ohm m)	True dimensions (m)			Estimated dimensions (m)			Estimated resistivity (Ohm m)	Error (%)			
		D	W	H	D	W	H		D	W	H	R
Conductive cavity	10	1.25	3	3	1.33	2.99	2.17	9.53	6.4	0.3	28	5
Resistive cavity	100	1.25	3	3	1.26	3.4	3.2	94.8	1	13	11	5.2
Real model	-	0.8	2.9	1.4	1.1	2.67	1.2	176300	27	8	14	-

Table 1.

Quantitative analysis of the accuracy of the ANN model, where 'D' is depth, 'W' is width, 'H' is height, and 'R' is resistivity.

Conclusion

The commonly applied smoothness based inversion is not ideal for imaging buried targets characterized by sharp resistivity edges, since it generates models characterized by a smooth distribution of resistivities over a wide range of values. In this paper, the author proposes simple procedures for partly offsetting the pitfalls that result from applying the smoothness-based regularization approach for the reconstruction of such targets. The reconstruction of the target's geometries and resistivity using the ANN is significantly improved compared with results of the watershed algorithms and smoothness constraint inversion. One advantage of the proposed approach is that it can be directly applied to the inverted resistivity images, without needing the raw data. However, the performance of the neural networks when applied to real data depends on using a similar setup to that employed for creating and processing the synthetic data used for training the network. The processing steps described here could be applied on a wide range of applications such as locating archaeological targets (e.g., tombs), mapping the depth to a bedrock, locating sinkholes, etc.

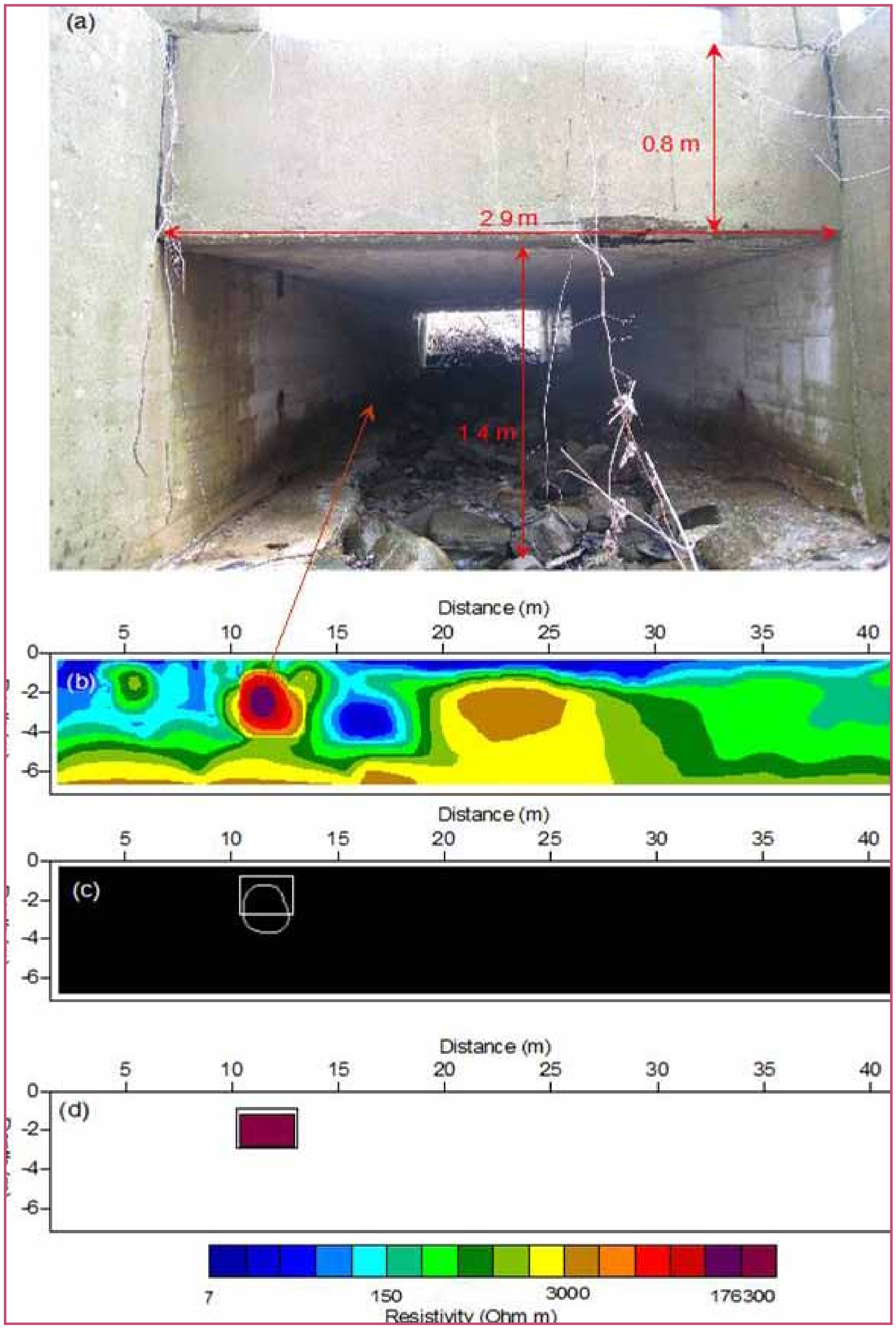


Figure 3. Results of the reconstruction process of the field model (a) subsurface tunnel (b) smooth section (c) detected boundary based on b (d) neural networks section (box denote true target outline).

References

Barraud, J., 2006. The use of watershed segmentation and GIS software for textural analysis of thin sections, J. Volcanol. Geotherm. Res. 154, 17–33.

Binley, A. and Kemna, A., 2005, Electrical Methods, In: Hydrogeophysics by Rubin and Hubbard (Eds.), 129-156, Springer.

Blaschek, R., Hordt, A. Kemna, A., 2008. A new sensitivity-controlled focusing regularization scheme for the inversion of induced polarization data based on the minimum gradient support. Geophysics. 73, NO. 2, F45–F54.

Elwaseif, M., Slater, L., in press. Quantifying tomb geometries using watershed algorithms, Journal of Archaeological Science. DOI 10.1016/j.jas.2010.01.002

Roueff, A., Chanussot, J., Mars, J. Nguyen, M.Q., 2004. Unsupervised separation of seismic waves using the watershed algorithm on time-scale images. Geophysical Prospecting. 52, Issue 4, 287 – 300.

Slater, L., Binley, A., 2006. Engineered barriers for pollutant containment and remediation in: Vereeken, H., Binley, A., Cassiani, G., Revil, A. Titov, K. (Eds.), Applied Hydrogeophysics. NATO Science Series IV, Earth and Environmental Sciences, Springer, pp. 293-317.

Smith, M., 1993. Neural Networks for Statistical Modeling. Van Nostrand Reinhold, New York.

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.

Save the Dates!

The Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) provides geophysicists, engineers, geoscientists and end-users from around the world an opportunity to meet and discuss near-surface applications of geophysics and learn about recent developments in near-surface geophysics. SAGEEP is internationally recognized as the leading conference on the practical application of shallow geophysics. Near-surface geophysics has developed into a valuable tool applied to a wide range of needs and SAGEEP is the one conference where you'll be exposed to the latest developments, equipment and software. It's also where you'll update skills... and contacts.

SAGEEP 2010 is offering exceptional educational opportunities in a quintessential mountain village setting: Keystone, Colorado. April in the Rockies can mean outdoor dining or nearby downhill skiing—but, no matter how you choose to spend your free time, epic scenery and 300 days of sunshine a year make Keystone a perfect SAGEEP 2010 location. Easy access from Denver, Colorado (DIA - Denver International Airport) via a shuttle service, its 21st century conference facilities, free WI-FI in the conference center, your choice of hotel, condo or lodge accommodations, free parking and a fantastic in-town transportation system assure attendees of a memorable and worthwhile SAGEEP experience in Keystone, Colorado.

Call for Sessions/Call for Session Chairs

SAGEEP 2010 conference planners are **seeking session chairs**. Proposed SAGEEP 2010 sessions listed below. Also being accepted are **session title suggestions**.

Call for **Session Ideas Deadline**	Aug. 14, 2009	Call for **Papers**	Sept. 14, 2009
Call for **Student Poster Abstracts**	Sept. 14, 2009	**Paper Deadline**	Dec. 18, 2009

Dam and Levee Session • Near Surface Geophysics in Government Stimulus • Military Uses of Geophysics • Rock Mechanics Session • Infrastructure • Tunneling • Hydrogeology • Urban Geophysics • Salt-Water Intrusion • Geochemistry • Energy Session • Uranium Session • Extreme Geophysics • GPR Session • Geophysical Instruments & Compliance with National Calibrations & Standards • Near-surface Geophysics on Mars

SAGEEP 2010 General Chair
Victor F. Labson, Ph.D.
e-mail: vlabson@usgs.gov

SAGEEP 2010 Technical Chair
James J. LoCoco, C.P.G.
e-mail: jim.lococo@mountsopris.com

1720 South Bellaire Street, Suite 110
Denver, CO 80222-4303
(303) 531-517
Fax: (303) 820-3844
E-mail: staff@eegs.org
Web: www.eegs.org

SAGEEP 2010
April 11-15, 2010
Keystone, Colorado USA

SAGEEP is the leading international conference on non-invasive technology for engineering and environmental site characterization. Approximately 400 professionals in the environmental and engineering geophysical community will attend this year's event. Exhibiting companies receive one full complimentary conference registration and two complimentary exhibit personnel registrations for each paid 10' x 10' booth space occupied. So, take advantage of your opportunity for quality exposure at this prestigious symposium.

Exhibitors—Space Available

Who should exhibit? Geophysical and geo-engineering service companies; developers and distributors of geo-scientific hardware and computer software; college/universities; government agencies; manufacturers and sales representatives of geophysical and geo-scientific instruments, equipment, and related supplies; publishers of scientific books and journals; research institutes; and scientific associations. Beginning in August, 2009, access the EEGS web site (www.eegs.org, then click the SAGEEP button and Exhibitor tab), for the SAGEEP 2010 Exhibitor Prospectus.

For more information or to secure your exhibit space at SAGEEP 2010, contact:
Marac Enterprises
Micki Allen, Exhibit Manager SAGEEP 2010
101-345 Renfrew Drive
Markham, Ontario, L3R 9S9, Canada
Phone: 905.474.9118
Fax: 905.474.1968
E-mail: mickiallen@marac.com

Environmental and Engineering Geophysical Society

1720 S. Bellaire Street, Ste. 110
Denver, CO 80222-4303
(303) 531-517
Fax: (303) 820-3844
E-mail: staff@eegs.org
Web: www.eegs.org

DGG 2010
70th Annual Conference of the German Geophysical Society

March 15-18, 2010, Bochum, Germany

We all would like to invite you to the 70th annual conference of the German Geophysical Society (DGG) in Bochum (*http://www.dgg2010.ruhr-uni-bochum.de/en*). It will take place at the Ruhr-University Bochum from 15th to 18th of March 2010.

In the heart of the Ruhr Area, Bochum had its time of prosperity sparked by coal mining and the iron and steel industry. Today still evidence of that industrial period may be found everywhere throughout the city. The famous Deutsches Bergbaumuseum which is also widely known beyond Bochum treats the topic of the industrial times in the Ruhr Area. After coal mining was ceased in the 1970s, today service industries and high technology are of importance and the Ruhr-University plays an exceptional role in local urban developement. The high quality of life that the region offers between urban liveliness and rural quietness may be one reason why the Ruhr Area will host the European Capital of Culture in 2010.

In 1965, the Ruhr-University Bochum was the first German university built after World War II. With its 20 faculties gathered on one campus it evolved to one of the biggest universities in Germany with a very high reputation in research matters. The special architectural concept well integrates the campus into its surrounding nature and at the same time allows for a very close interdisciplinary cooperation and research between the faculties. These excellent conditions may be one reason for the university's numerous Collaborative Research Centres ("Sonderforschungsbereiche" SFB) funded by the German Research Foundation (DFG). In geosciences the SFB 526 "Rheology of the Earth" is of importance, where geodynamic processes from upper crust to the subduction zone and controlling material propties are examined. Geophysical aspects such as rock physics, earthquakes, geodynamics of the lithsphere as well as numeric modelling and visualization will be central topics of the conference. Also the role of geophysics for future energy supply will be focused on. A social programme and several excursions complete the conference.

Glückauf!

We are looking forward to welcoming you to Bochum at the anniversary conference of the German Geophysical Society in 2010.

Yours Wolfgang Friederich and Jörg Renner (local organizing committee).

Summer of Applied Geophysical Experience (SAGE) 2010

The SAGE program is a three-week graduate and advanced undergraduate course of instruction and research in exploration geophysics based in Santa Fe, New Mexico. The Los Alamos branch of the Institute of Geophysics and Planetary Physics (IGPP) is sponsoring SAGE for its 28th year. The **core** Program (all students) will be held Sunday, June 20 (arrival on Saturday, June 19), through Sunday, July 11, 2010. The cost will be $450, of which $100 is due with the application.

We particularly encourage applications from qualified:

1) students who are U. S. citizens or Permanent Residents (PR) who will have completed their *junior* year and completed the requisite physics and math before SAGE,

2) U. S. *graduate* students in all stages of their careers, and

3) International students and Professionals.

Continued support from the U. S. **National Science Foundation Research Experience for Undergraduates (REU)** program will allow us to extend SAGE extra days for undergraduate students who are U. S. citizens/PR. For students qualifying as US/PR undergraduates, SAGE will begin on Thursday, June 17 (arrival on Wednesday, June 16). For these students, stipend and travel support will be automatic if accepted, and the $450 fee will be waived. For *all* students, SAGE will extend through evening dinner on Sunday, July 11, 2010. Departure will be Monday morning, July 12, for most students.

Students should have a quantitative background and some introduction to geophysics, though they need not be geophysics majors. We particularly welcome math/physics majors and other students considering careers in geophysics. As an example, students should have successfully completed a minimum of one year (two semesters or three quarters) of physics (through Electricity & Magnetism) and a minimum of three semesters of calculus (four preferred). Structural geology and/or introductory geophysics are recommended but not required.

Please note that the deadline for SAGE 2010 is 5:00 PM MDT on Friday, March 26. Evaluations will begin the following week. We require a letter of interest, two references, proof of insurance, and complete transcripts (informal OK). See the SAGE web site for application and reference forms, and more detailed information.

If you have questions or need more information, please call the IGPP office at (505) 663-5291 or e-mail Georgia georgia@lanl.gov. For further details and a description of the program, please refer to http://www.sage.lanl.gov.

Los Alamos NATIONAL LABORATORY EST. 1943

Office of Science U.S. DEPARTMENT OF ENERGY

SAGE

SUMMER of APPLIED GEOPHYSICAL EXPERIENCE

NSF

ICEEG 2010

Chengdu China

4th International Conference on Environmental and Engineering Geophysics

June 14~17, 2010, Chengdu, China

The Near-Surface Geophysics and Geohazards

First Announcement

http://www.iceeg.cn/

Sponsoring Hosts

Chinese Geophysical Society
National Natural Science Foundation of China
China University of Geosciences (CUG)
Chengdu University of Technology

Supporters

Chengdu University of Technology

Conference Summary

Geohazard is a kind of natural hazards. In recent years, Geohazards occurred frequently in China and caused serious dangers to people's lives and property. As a branch of geophysics, near-surface geophysics is mainly applied in the detection and assessment rock-soil slopes, ground deformation, mine disasters, and water resource deterioration. The geophysical techniques are non-intrusive, cost-effective, large-scale or small-scale, and can remotely acquire three-dimensional, and even four-dimensional representations of underground media. Due to the broad application of geophysical techniques in the environmental and engineering fields, they are of great significance for the sustainable development of human society.

Having successfully convened the 1st, 2nd, and 3rd International Conference on Environmental and Engineering Geophysics in 2004, 2006, and 2008, respectively, we are once again pleased to be hosting the 4th International Conference on Environment and Engineering Geophysics in Chengdu, China, June 14-17, 2010. It is our pleasure to invite you to participate in this exciting event and to enjoy the hospitality of Wuhan.

This conference is designed to be a wonderful opportunity for all attendees to share your knowledge, experience, and friendship. We strongly believe that you will find great value in your participation in the conference and exhibits. Please do not miss this historic opportunity to present your work.

Invited speakers

Invited distinguished geophysicists and researchers from the Unite States, Canada, Europe, Australia and Asia will present their studies.

Conference topics

The entire spectrum of near-surface geophysical methods and applications.

Call for papers

This conference will offer an opportunity to all geophysicists and engineers to present recent achievements including case studies and theoretical studies in related techniques, software and instruments. The manuscript should not exceed 6 pages (including figures) with an abstract of about 300 words.

Manuscripts should be submitted via email to yechengming@cdut.edu.cn.

The deadline for the manuscripts is December 31, 2009.

Publication of Proceedings

The conference proceedings will be published by an American publisher and be delivered to the International Citation Institution.

Venue and time

The conference will be held on the campus of Chengdu University of Technology, Chengdu, China, June 14-17, 2010.

Registration

Delegate Rate: USD $200; Student Rate: USD $150; 5% off for early birds (early bird deadline is April 30, 2010). Registration includes: icebreaker, keynote session, oral and poster presentations, exhibits, conference program book, Proceedings volume, and all conference lunches and dinners. **Registration will begin on September 1, 2009. You may register via E-mail or fax.**

Hotels

Accommodations during the conference are available on the campus of Chengdu University of Technology. Hotels near the campus are also available.

Social program

Hospitality Suites: Tour of modern and antique places in the city of Chengdu which offer culture, hospitality and gastronomy in original surroundings and downtown shopping.

Language

The working languages of the conference will be English and Chinese.

Post-session trip

The post-session trip will be designed to visit ruins of Wenchuan Earthquake Park.

Ruins of Wenchuan Earthquake Park

Sponsorship Opportunities

Three levels of exhibiting sponsorship are available as follows:

GOLD: USD $2,500, including 10 m^2 exhibit space, 3 complimentary registrations, ten volumes of proceedings (5 in English, 5 in Chinese), and one page in the Conference Program & Exhibitors Directory designed to introduce your company.

SILVER: USD $1,500, including 6 m^2 exhibit space, 1 complimentary registration, 4 volumes of proceedings (2 in English, 2 in Chinese), and a half of a page in the Conference Program & Exhibitors Directory designed to introduce your company.

BRONZE: USD $800, including 1 complimentary registration, 2 volumes of proceedings (1 in English, 1 in Chinese), and one third of a page in the Conference Program & Exhibitors Directory designed to introduce your company. In addition, the icebreaker and farewell dinner during the conference are complimentary for sponsors.

The deadline for booking exhibit space is May 15, 2010. Please visit the website http://www.iceeg.cn/ or contact the organizing committee for details.

About Chengdu

Chengdu, located in southwest People's Republic of China, is the capital of Sichuan province and a sub-provincial city. Chengdu is also one of the most important economic centers, transportation and communication hubs in Southwestern China. More than four thousand years ago, the prehistorical Bronze Age culture of Jinsha established itself in this region. The fertile Chengdu Plain, on which Chengdu is located, is called *Tianfuzhi guo* in Chinese, which literally means "the country of heaven", or more often seen translated as "the Land of Abundance". It was recently named China's 4th-most livable city by China Daily.

Giant Panda, Chengdu

Organizing Committee

Honorary Chair:

Guangding Liu (Honorary Chair of China Geophysical Society)
Zhenhua He (Former President of CDUT)
Jingao Zhang (President of CUG)

Executive Chairs:

Runqiu Huang (Professor, CDUT)
Xuben Wang (Professor, CDUT)

Executive Co-Chairs:

Jianghai Xia (Senior Scientist, Kansas Geological Survey, The University of Kansas, USA)
Yaoguo Li (Associate Professor, Colorado School of Mines, USA)
Sheng Yu (PhD, Director of Geophysical Department, Natural Science Foundation of China)
Yixian Xu (Professor, CUG)

General Secretaries:

Jianguo Yan, Jing Wang
Shipeng Zhang, Jijun Jia

Technical Secretaries:

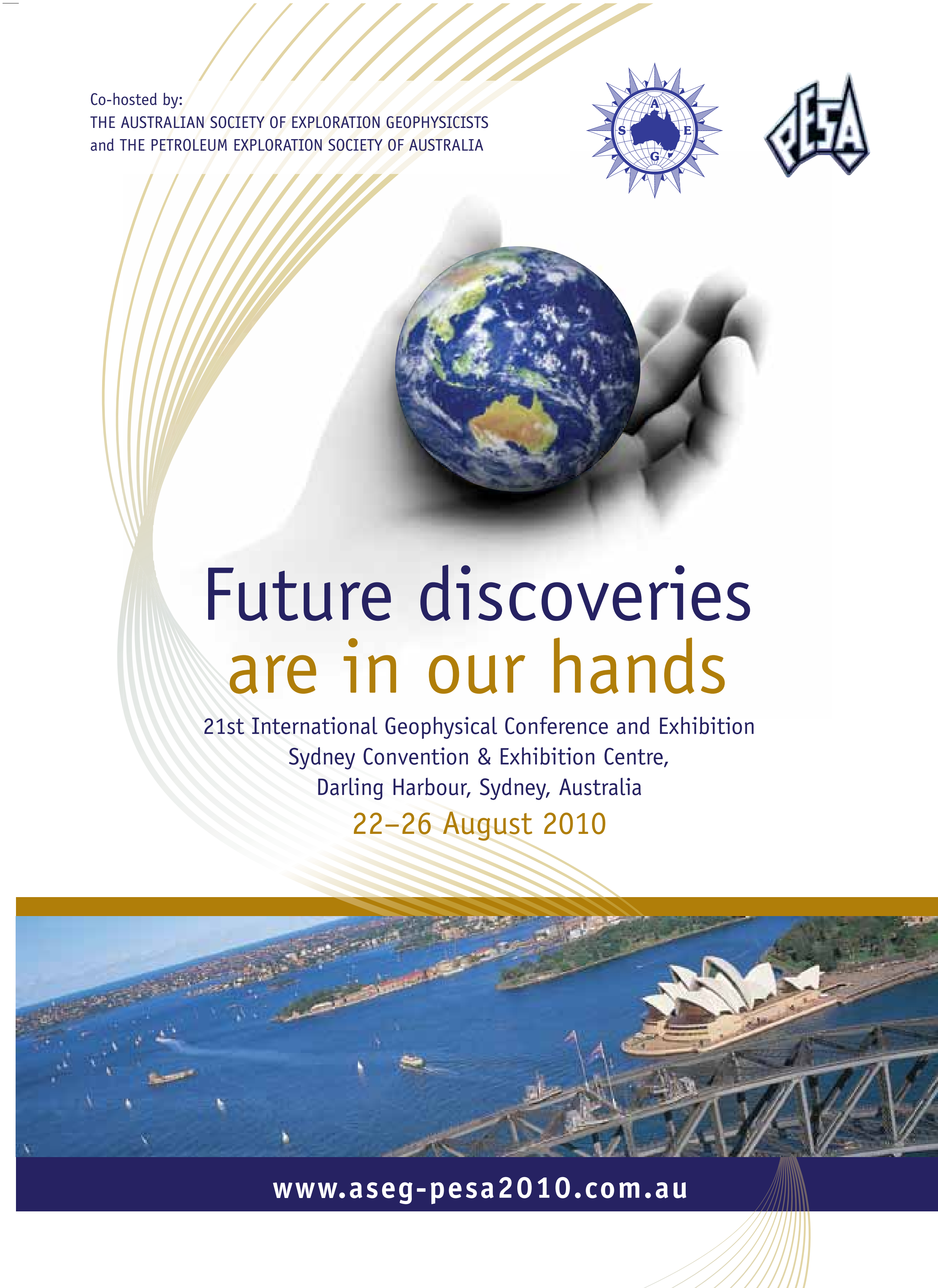
Chengming Ye, Yinhe Luo

Registration Secretaries:

Chun Lin

For more details of the conference, please visit our website http://www.iceeg.cn/, or contact:

ICEEG2010
Key Lab of Earth Exploration & Information Techniques of Ministry of Education
Chengdu University of Technology
Chengdu, Sichuan 610059
China
Phone: (011 86 28) 8407 6279 (011 86 28) 8407 9681
Fax: (011 86 28) 8407 9681
Email : yechengming@cdut.edu.cn; linchun119@163.com



Co-hosted by:
THE AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS
and THE PETROLEUM EXPLORATION SOCIETY OF AUSTRALIA
A S E G
PESA
Future discoveries
are in our hands
21st International Geophysical Conference and Exhibition
Sydney Convention & Exhibition Centre,
Darling Harbour, Sydney, Australia
22–26 August 2010
www.aseg-pesa2010.com.au

State-of-the-Art in Multi-Dimensional Electromagnetics: A Special Session in Honor of Gerald W. Hohmann

October 17-22, 2010, Denver, CO

This special session honoring the late Gerald W. (Jerry) Hohmann invites contributions that focus on the role of advanced multi-dimensional forward modeling, inversion and field methods in geophysical applications of electrical and electromagnetic methods. The session covers implementation of new field systems and procedures to achieve dense lateral coverage, and the use of modern analytical and numerical techniques for interpretation or inversion of EM field data. Applications can range from hydrocarbon, mineral, geothermal and groundwater exploration, to environmental monitoring and carbon sequestration studies.

This announcement is for anyone considering, or who has completed, the submission of a paper to the SEG meeting. The SEG online system does not have a special-session selection feature. If you would like your paper to be presented in this session, please inform Louise Pellerin (pellerin@ak.net) and she will coordinate with SEG. Depending on the number of submissions both an oral and a poster session are possible. Deadline for abstract submission is April 7, 2010, at 5:00 p.m. Central Daylight Time.

Gerald W. (Jerry) Hohmann (Ph.D. 1970, University of California at Berkeley) was Professor of Electromagnetic Geophysics at University of Utah from 1977 until his untimely death in 1992 at age 51. Jerry was a pioneer in quantitative analysis of electromagnetic methods, and together with his mentor and fellow professor Stan Ward, built a world-class research effort in applied geophysics at this institution. Jerry's exacting standards were coupled with an easy-going nature that induced students to high achievement in a supportive environment.

This session is being organized by the Gerald W. Hohmann Memorial Trust for Research and Teaching of Applied Electrical Geophysics. The Trust sponsors career achievement awards and student scholarships with the SEG, and holds quadrennial international symposia on EM modeling and inversion.

12th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst™

January 10-14, 2011, St. Louis, Missouri

This is the 12th in this series of highly successful interdisciplinary conferences which were first organized by the Florida Sinkhole Research Institute in 1984 as a means for geologists and geographers, who study how and where karst develops and how sinkholes form, to interact with engineers, planners and others, who must apply this information to build and maintain society's infrastructure and protect our environment. Since the first meeting in 1984, these biennial conferences have grown into the single most important international professional meeting concentrating on the practical application of karst science.

The goal of this conference is to share knowledge and experience among disciplines by emphasizing scientific and technological aspects of karst that have practical applications, together with case histories of those applications. Since karst topography impacts ground and surface water resources, waste disposal and management, highways and other transportation facilities, structural foundations and utilities and other infrastructure, civil, geotechnical and environmental professionals should all attend this most relevant conference.

For more information please visit the conference web site at http://www.pela.com/sinkhole2011.htm

GEOMETRICS INTRODUCES THE METALMAPPER UXO DISCRIMINATION SYST

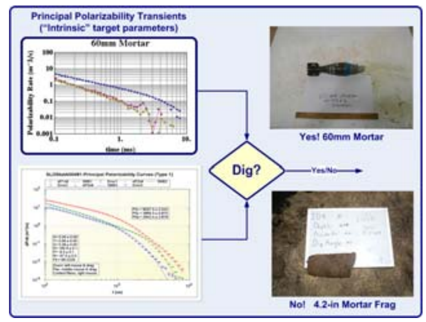
COMM

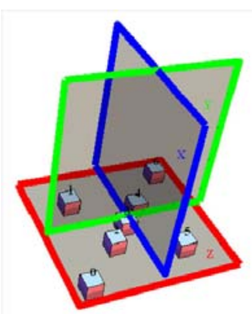
PROGRAMS

From Bark Hoekstra, Product Manager, Geometrics

The MetalMapper, supported in its development by several major governmental agencies including SERDP/ESTCP and NAVEODTECHDIV, is geared towards reducing the high cost for cleaning up sites contaminated with unexploded ordnance (UXO). A major emphasis of these groups is the commercialization of the technologies developed under these programs.

The MetalMapper system is a step forward in the discrimination of Unexploded Ordnance (UXO) from other buried metallic scrap. It uses the proven methods of Time Domain EM (TDEM) to identify buried metal, but has significantly more capabilities than existing commercially available systems. The TDEM method works by inducing currents in the ground. Currents in the soils quickly decay away, but if there are metallic objects in the ground the currents decay much more slowly. The MetalMapper system measures the magnetic fields caused by the currents in the metallic objects and then uses that information to compute the size and shape of the buried object.





The system consists of 3 orthogonal transmitter loops that are 1m x 1m in size. There are 7 (seven) 3-component receiver coils mounted within the horizontal transmitter coil. The receiver coils are wire wrapped on 10 cm x 10 cm cubes

The system can be used in two different modes. The first is a dynamic mapping mode where only the horizontal transmitter coil is used and a shorter recording window is employed. The second mode is a static mode where once a target has been identified the array is placed on top of the target. In this mode all three transmitter coils are fired sequentially and a longer recording window is employed.

The system is controlled by a compact PC, running software that controls the acquisition parameters, logs the data and also provides feedback to the operator on the positioning of the system and data quality. The system is highly configurable allowing the operator to vary almost every data acquisition parameter including decay length, number of decays averaged, transmitter coils used and others. The displays available to the operator are equally flexible, so the operator can see the information necessary for whatever type of survey is being performed.

This is a map *(Image 3)* derived from the MetalMapper data. The targets are identified by bright pink features in the data. Similar production rates to currently used systems are obtainable, but the MetalMapper has increased positional accuracy because of the multiple small receiver coils instead of a

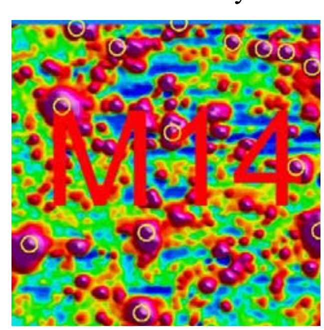


Image 3

single large coil. Further research is currently being conducted to provide the ability to determine the size and depth of the objects from dynamically collected data.

The results from the latest demonstration of the MetalMapper at a site in San Luis Obispo, California showed that the MetalMapper can provide information that is a huge leap forward in the ability to discriminate UXO objects from other metallic objects. The receiver operating curves (ROC) shown in *(Image 4)* show that all UXO objects would be excavated with a minimal number of pieces of scrap metal.

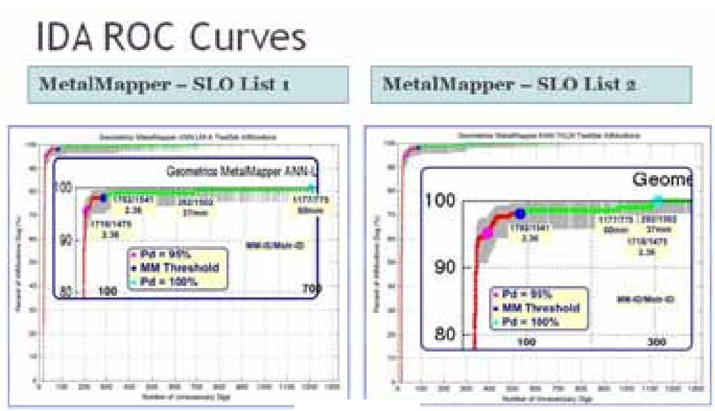


Image 4

Instead of digging thousands of metallic scrap items to find one or two UXO items, which is typical of most UXO remediation projects, the MetalMapper identified all the approximately 200 UXO objects while only selecting 90 metallic scrap objects. This type of information allows a UXO remediation to proceed much quicker and at lower cost, allowing valuable property to be used productively.

Software is provided with the MetalMapper to directly import the MetalMapper files into commonly used software packages such as *Geosoft Montaj*. In addition a .Net library is provided to allow other programs to easily access the data..

Geometrics has supplied the world with rugged, portable, easy-to-use, and technologically-innovative geophysical instruments — and responsive, worldwide customer support, since 1969. Our line of seismographs, magnetometers, and geoelectrical instruments lets you produce detailed reports, graphs, and maps of the earth's subsurface for:

- *Mineral, oil, and gas exploration*
- *Unexploded ordnance mapping*
- *Geotechnical engineering studies*
- *Archaeology*

Learn why colleges and universities, research institutions, government agencies, and exploration firms depend on our 40 years of field experience at www.geoemetrics.com.

Alpha GeoScience

Application Review – TEM

terraTEM System

Monex GeoScope

The terraTEM is a new transient electromagnetic survey system designed and constructed in Australia. It incorporates a 10 Amp transmitter and a true simultaneous 500 kHz 3-component receiver. The unit is powered by an external 24 V battery pack system allowing 6-8 hours of continuous operation. An inbuilt GPS is mounted on the front panel, allowing location information to be automatically recorded with soundings. All connectors are external to the case allowing easy transportation without having to shutdown between sites.

The user interface comprises a 15" colour LCD panel and a touch-screen. Menus are designed to allow intuitive and rapid transition between critical acquisition parameters and data display. Spectral analysis, combined with DSP options, allows the user to design specific filters to suit local site conditions. A diagnostic menu provides access to a spectrum analyser as well as time-domain views of the input signal for rapid troubleshooting or optimisation of acquisition parameters to ambient site conditions.

Data is stored in an expandable 1 GByte solid-state memory, this provides the user with essentially unlimited storage space (up to 500,000 soundings), making the terraTEM system ideal for rapid, high-resolution surveys. System parameters are stored automatically with each sounding for post-survey quality assurance. Data is transferred using a USB flask memory stick. The terraTEM is packaged with data reduction and processing software and can generate on-site standard profile and decay plots, apparent conductivity pseudo-sections, and contour plan maps. Images can be saved as bitmaps and inserted directly into reports. All data in this brochure was derived from the internal terraTEM software. Synchronisation with an external transmitter is optional.

The terraTEM has been developed and manufactured by Monash Geoscope and distributed worldwide by Alpha Geoscience.

IGS

International Geophysical Services, LLC
171 South Van Gordon St. Unit A Lakewood, CO 80228 USA

For more information, contact:

Ron Bell
Consulting Geophysicist

303-462-1466
rbell@igsdenver.com

www.igsdenver.com

International
Geophysical
Services, LLC

February 12, 2010 - Denver, CO

International Geophysical Services, LLC (IGS, LLC) is the exclusive US Sales Representative for the award winning TerraTEM Time-domain EM data acquisition system designed and manufactured by Monex Geoscope of Selby, Victoria Australia.

To learn more about this *modern and versatile* TEM data acquisition system, please contact:

Ron Bell, Consulting Geophysicist
303-462-1466 rbell@IGSDenver.com.

The following notice is for an upcoming short course on the TEM Method. If you are a geoscientists or engineers unfamiliar with the technology but interested in learning more, OR if you are a geophysicist or geologist wishing to refresh your knowledge or learn about the latest advancements, this course is for you.

SHORTCOURSE OFFERING – SAGEEP 2010

SC-3: Application of Time-domain ElectroMagnetics to Ground-Water Studies

Date: Sunday, April 11, 2010
Instructors: David Fitterman, USGS Emeritus
Time: 8am - 5pm

Description:

Time-domain electromagnetic (TEM) sounding is well suited to many ground-water investigations ranging from mapping of saltwater intrusion, estimation of water quality, delineation of clay zones, and determination of aquifer geometry. Data can be acquired rapidly with minimal field-crew size compared to DC resistivity or seismic methods. The resolution of conductive targets is better than almost all electrical and electromagnetic methods. These attributes make it an ideal candidate for small- to regional-scale ground-water studies. This one-day course is aimed at geophysicists, hydrologists, and geologists who want to learn more about the potential and limitations of the method. The approach will be to begin with theoretical and model studies to understand capabilities and limitations, and follow with real-world field examples to illustrate what can happen in practice and how to deal with these situations. Topics covered include basic principles of TEM, calculation of TEM model response and it tells us, depth of exploration, effect of noise, data collection and processing, data interpretation, survey design, and suggestions about field work.

For more information, click on: http://www.eegs.org/sageep/courses.html

www.igsdenver.com

171 South Van Gordon St. Unit A, Lakewood, CO 80 USA tel: 303-462-1466

CALL FOR PAPERS

Geophysics for Dam Safety

Special Issue
of the
Journal of Environmental and Engineering Geophysics

The Journal of Environmental and Engineering Geophysics (JEEG) announces a Call for Papers for a special issue on geophysics for dam safety. The Dam Safety issue is scheduled for publication in March 2011. The special issue editor is Dr. Michael H. Powers, U.S. Geological Survey, Denver, CO. Sponsorship of this issue is still open.

Papers describing the successful use of one or more geophysical surveys to understand engineering issues of concern for dam safety risk assessment and/or remediation are sought. The issues can include foundation and/or embankment property measurements, fault analyses for earthquake hazard potential, basin studies to better understand hydrological risks, or other safety concerns. Preference will be given for papers with supporting information to substantiate the geophysical models. International contributions are encouraged. The final special issue can only accommodate a maximum or seven or eight papers, but all accepted papers will be considered for publication in other JEEG issues.

Papers can be submitted through the JEEG submission site, http://jeeg.allentrack.net. Indicate in the cover letter that the paper is for consideration in the Dam Safety special issue. The deadline for submissions is May 30, 2010.

Questions may be directed to:

Special Issue Editor—Michael H. Powers, mhpowers@usgs.gov
JEEG Editor—Janet Simms, Janet.E.Simms@usace.army.mil

Invitation to Participate in Symposium on Benchmarking Surface Wave Method

Deadline: March 31, 2010

All interested practitioners and researchers are invited to participate in a Surface Wave Benchmarking Symposium organized by the Geophysical Engineering Committee of the Geo-Institute of ASCE. The goal of the symposium is to document the state of different protocols, such as MASW, SASW and ReMi, for analyzing the surface wave data. The organizing committee invites all participants to contribute to the benchmarking exercise by analyzing a surface wave data set collected at a well-characterized site. The participants can also provide written papers for inclusion in a symposium that will be organized as part of the Geo-Risk Conference to be held in 2011. The deadline for contributing to this symposium is March 31, 2010.

Further detail and raw data collected with various methods can be downloaded from the following website: *http://saswbench.ce.ufl.edu*. Please forward any questions regarding the event to Dr. Dennis Hiltunen at *dhilt@ce.ufl.edu*.

One postdoc at the Colorado School of Mines

Induced polarization (time and frequency domains, development ofthe theory, field/lab and inversion of IP datasets) for contaminant plume investigations and permeability tomography For further details see *http://www.epa.gov/oamrtpnc/q0900194/index.htm*.The potential candidates can contact André Revil at *arevil@mines.edu* and Dale Werkema at *werkema.d@epa.gov*. The work will be performed at the Colorado School of Mines under the supervision of André Revil (dept of Geophysics, *http://www.andre-revil.com*) and co-supervision of Burke Minsley (USGS, *bminsley@usgs.gov*) and Dale Werkema (EPA). The candidate is expected to have excellent skills in numerical modeling.

Starting date: As soon as possible.

willowstick

11814 S. Election Road
Suite 100
Draper, UT 84020
TEL 801.984.9850 FAX 801.984.9851
www.willowstick.com

Geophysicist Position

Willowstick Technologies is looking to hire a staff geophysicist to help with the development of the AquaTrack technology. AquaTrack is a proprietary technology developed by Willowstick Technologies to map subsurface groundwater flows by directly energizing the water of interest. To read more about AquaTrack, please visit our website www.willowstick.com . We are a progressive company with great employees and good benefits and are looking for an individual to help continue Willowstick Technologies productivity.

We are looking for an individual with the following qualifications.

1. U.S. Citizen or Resident
2. Masters or doctorate degree in geophysics or geoscience.
    a. An interest in groundwater mapping and modeling.
    b. Experience with various electrical geophysical exploratory methodologies.
    c. Experience with inversion programming and modeling.
3. Good computer skills and experience with:
    a. Matlab programming
    b. ArcMap or other GIS software (not necessary but a plus).
    c. Excel
4. Excellent writing and communication skills

If you think you have the qualifications, please send a cover letter and resume to either Michael Wallace (mwallace@willowstick.com) or Mike Jessop (mjessop@willowstick.com).

Open Position: Senior Research/Project Geophysicist

Underground Imaging Technologies, Inc. (UIT) is a geophysical service company that specializes in 3D mapping for infrastructure projects. We are looking to expand our geophysical staff and to add resources to manage a large R&D grant we have recently received.

This position calls for a dual role based on several years of geophysics experience in the engineering, infrastructure and environmental areas. One role is daily project management of an R&D project with several subcontractors and reporting to a principal investigator within the company and to a government-funded agency. This role will be the main one for the first two years and then the successful applicant will follow the project into commercialization and field operations. The second role, as time permits, will be as a senior geophysicist in normal operations for geophysical applications in 3D utility mapping, other infrastructure mapping, brownfields site mapping, environmental mapping, UXO mapping and shallow mining applications.

Requirements: B.S. degree (or higher) in geophysics and 10 or more years experience in applying geophysical tools to engineering, infrastructure and environmental projects. The primary role will be in administering an R&D project that includes development of a multi-sensor geophysical system for mapping buried utilities. While geophysical experience in this area is necessary, R&D experience will be not necessary but would be a plus. The senior geophysicist will report to the project's principal investigator who has the responsibility of R&D oversight. As a day to day project manager, excellent communication skills in English, both written and oral are a required. Experience with GPR, various types of electromagnetic methods, and engineering seismic are desirable. Applicants must be US citizens or have a US work permit (green card). This is a full time, permanent position. Pay will be commensurate with experience. A full suite of expected benefits accompany the position including medical and dental insurance, 401K, and more. UIT is an equal opportunity employer.

Please send resume and references to: humanresources@uit-systems.com.

19 W British American Blvd, Latham, New York 12110 / (518) 783-9848 PHONE / (518) 783-9634 FAX / www.UIT-systems.com

Interested in EM methods? Want to share your software, instruments, data, or ideas? Want to learn more about EM and find expertise for collaboration? Want to experiment with new applications?

Welcome to OpenEM.org!

OpenEM.org is a community resource for electromagnetic geophysics. The OpenEM virtual institute as it develops will include several continuously evolving core resources:

- a repository for community-supported open source software for EM data analysis, forward and inverse modeling and interpretation
- links to data management centers with extensive collections of unrestricted EM data sets and derived data products
- tools for requesting access to shared EM instruments both through the National Geoelectromagnetic Facility and through a clearinghouse for PI-maintained instruments that may be available for loan
- a community forum for free exchange of technical information
- Support for special interest groups (SIGs) within EM geophysics
- collaborative workgroup tools to promote multi-institutional experiment planning and execution
- hosted “webinars” on EM geophysics, to serve as a national “departmental” monthly seminar series
- academic-industry showcase of EM geophysics products and services

EM geophysics job postings, studentships, postdoctoral opportunities OpenEM is open to everyone. While it is designed primarily to serve the interests of US-based EM geophysicists, there are no restrictions on access by any individual or group no matter their geographic location. OpenEM is dedicated to free exchange of information, to establishing and promoting open standards for software interoperability, data exchange, and model definition. Our goal is to make EM geophysics accessible as widely as possible; to take it out of the specialist laboratory and into the field. The OpenEM virtual institute spans the full range of terrestrial, airborne and marine EM geophysics, including DC resistivity, induced polarization methods, passive and controlled source EM, transient/time domain EM, magnetotellurics including CSAMT, AMT and RFMT, and geomagnetic depth sounding and related methods.

Join EEGS Now!

Environmental and Engineering Geophysical Society

Membership Application

1720 South Bellaire Street | Suite 110 | Denver, CO 80222-4303
(p) 011.1.303.531.7517 | (f) 011.1.303.820.3844 | staff@eegs.org | www.eegs.org

Contact Information

Salutation	First Name	Middle Initial	Last Name	Nickname

Company/Organization	Title

Street Address	City & State

Zip	Country	Direct Phone	Mobile Phone	Fax

Email	Website

About Me: Interests & Expertise

In order to identify your areas of specific interest and expertise, please check those that apply:

Classify Association

- ☐ Consultant
- ☐ User of Geophysical Services
- ☐ Student
- ☐ Geophysical Contractor
- ☐ Equiment Manufacturer
- ☐ Software Manufacturer
- ☐ Research/Academia
- ☐ Government Agency
- ☐ Other ____________

Classify Interest or Focus

- ☐ Archaeology
- ☐ Engineering
- ☐ Environmental
- ☐ Geotechnical
- ☐ Geotechnical Infrastructure
- ☐ Groundwater
- ☐ Hazardous Waste
- ☐ Humanitarian Geophysics
- ☐ Mining
- ☐ Shallow oil & Gas
- ☐ UXO
- ☐ Other ____________

Specific Areas Involved

- ☐ Borehole Geophysical Logging
- ☐ Electrical Methods
- ☐ Electromagnetics
- ☐ Gravity
- ☐ Ground Penetrating Radar
- ☐ Magnetics
- ☐ Seismic
- ☐ Other______

Professional/Scientific Societies

- ☐ AAPG
- ☐ AEG
- ☐ ASCE
- ☐ AWWA
- ☐ AGU
- ☐ EAGE
- ☐ EER1
- ☐ GeoInstitute
- ☐ GSA
- ☐ MGLS
- ☐ NSG
- ☐ SEG
- ☐ SSA
- ☐ SPWLA
- ☐ Other ___________

Interested in Participating on Standing Committees?

- ☐ Government Affairs
- ☐ Research
- ☐ Publications
- ☐ Awards
- ☐ Corporate Affairs
- ☐ Web Page
- ☐ Student

Membership Categories

Circle the desired Membership Category amount.

	Standard (I prefer to access JEEG online and do not wish to receive a printed issue)	**Printed** (I prefer to receive a printed JEEG)
Individual*	$90	$100
NEW **Retired**	$50	N/A
Student	$20	$60
Corporate Donor	$650	$660
Corporate Associate	$2,400	$2,410
Corporate Benefactor	$4,000	$4,010
To view the qualification for the New Developing World categories, please access http://www.eegs.org and click on Membership	**Standard** (I prefer to access JEEG online and do not wish to receive a printed issue)	**Printed** (I prefer to receive a printed JEEG)
NEW **Developing World Category***	$50	$100

Category Descriptions and Newly Expanded Benefits

Individual and Developing World Category Memberships:

- Access to the **online EEGS Research Collection** resource—online access to the complete *Journal of Environmental and Engineering Geophysics* (*JEEG*) and proceedings archives of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP)
- The option of receiving a printed *JEEG* or accessing an electronic issue
- Subscription to the ***FastTIMES*** Newsletter
- **Preferential** registration **fees** for **SAGEEP**
- **Networking** and continued **communication** on issues of interest to the organization

Retired Membership:

- Includes all the benefits of the Individual Membership category. Applicants must approved by the EEGS Board of Directors. Please submit a written request for the Retired Category, which will be reviewed by the Board of Directors.

Note: This category does not include the option for a printed JEEG - if you wish to receive a printed JEEG, please sign up under Individual Membership Printed

Student Membership:

- Includes all the benefits of the Individual Membership category
- Submission must include current student ID or documentation of graduation date (applies to recent graduates for two years after graduation)

Corporate Donor Membership:

- Includes all the benefits of the Individual Membership
- Full conference registration for the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP)
- A link on the EEGS Website
- Listing with corporate information in *FastTIMES*
- 10% discount on advertising in the *JEEG* and *FastTIMES*

Corporate Associate Membership:

- Includes all the benefits of the Individual Membership for two (2) people
- An exhibit booth at the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP)
- Ability to insert marketing materials in the SAGEEP delegate packets
- A link on the EEGS website
- Listing with corporate information in *FastTIMES*
- 10% discount on advertising in the *JEEG* and *FastTIMES*

Corporate Benefactor Membership:

- Includes all the benefits of Individual membership in EEGS for two (2) people
- Two exhibit booths at the Symposium on the Applications of Geophysics to Engineering and Environmental Problems (SAGEEP)
- Ability to insert marketing materials in the SAGEEP delegate packets
- A link on the EEGS website
- Listing with corporate information in *FastTIMES*
- 10% discount on advertising in the *JEEG* and *FastTIMES*

FOUNDATION CONTRIBUTIONS

FOUNDERS FUND

THE FOUNDERS FUND HAS BEEN ESTABLISHED TO SUPPORT COSTS ASSOCIATED WITH THE ESTABLISHMENT AND MAINTENANCE OF THE EEGS FOUINDATION AS WE SOLICIT SUPPORT FROM LARGER SPONSORS. THESE WILL SUPPORT BUSINESS OFFICE EXPENSES, NECESSARY TRAVEL, AND SIMILAR EXPENSES. IT IS EXPECTED THAT THE OPERATING CAPITAL FOR THE FOUNDATION WILL EVENTUALLY BE DERIVED FROM OUTSIDE SOURCES, BUT THE FOUNDER'S FUND WILL PROVIDE AN OPERATION BUDGET TO "JUMP START" THE WORK. DONATIONS OF $50.00 OR MORE ARE GREATLY APRECIATED. FOR ADDITIONAL INFORMATION ABOUT THE EEGS FOUNDATION, VISIT OUR WEBSITE AT HTTP://WWW.EEGS.ORG AND CLICK ON MEMBERSHIP, THEN "FOUNDATION INFORMATION". YOU MAY ALSO ACCESS THE EEGS FOUNDATION AT HTTP://WWW.EEGSFOUNDATION.ORG.

FOUNDATION FUND TOTAL: ____________________

STUDENT SUPPORT ENDOWMENT

THIS ENDOWED FUND WILL BE USED TO SUPPORT TRAVEL AND REDUCED MEMBERSHIP FEES SO THAT WE CAN ATTRACT GREATER INVOLVEMENT FROM OUR STUDENT MEMBERS. STUDENT MEMBERS ARE THE LIFEBLOOD OF OUR SOCIETY, AND OUR SUPPORT CAN LEAD TO A LFETIME OF INVOLVEMENT AND LEADERSHIP IN THE NEAR SURFACE GEOPHYSICS COMMUNITY. DONATIONS OF $50.00 OR MORE ARE GREATLY APRECIATED. FOR ADDITIONAL INFORMATION ABOUT THE EEGS FOUNDATION, VISIT OUR WEBSITE AT WWW.EEGS.ORG AND CLICK ON MEMBERSHIP, THEN "FOUNDATION INFORMATION". YOU MAY ALSO ACCESS THE EEGS FOUNDATION AT HTTP://WWW.EEGSFOUNDATION.ORG.

STUDENT SUPPORT ENDOWMENT TOTAL: ____________________

CORPORATE CONTRIBUTIONS

THE EEGS FOUNDATION IS DESIGNED TO SOLICIT SUPPORT FROM INDIVUDALS AND CORPORATE ENTITIES THAT ARE NOT CURRENTLY CORPORATE MEMBERS (AS LISTED ABOVE). WE RECOGNIZE THAT MOST OF OUR CORPORATE MEMBERS ARE SMALL BUSINESSES WITH LIMITED RESOURCES, AND THAT THEIR CONTRIBUTIONS TO PROFESSIONAL SOCIEITES ARE DISTRIBUTED AMONG SEVERAL ORGANIZATIONS. THE CORPORATE FOUNDER'S FUND HAS BEEN DEVELOPED TO ALLOW OUR CORPORATE MEMBERS TO SUPPORT THE ESTABLISHMENT OF THE FOUNDATION AS WE SOLICIT SUPPORT FROM NEW CONTRIBUTORS. AS SUCH, CORPOATE FOUNDERS WILL RECEIVE SPECIAL RECOGNITION FOR DONATIONS EXCEEDING $2500 THAT ARE MADE BEFORE MAY 31, 2010. THESE SPONSORS WILL BE ACKOWLEDGED IN A FORM THAT MAY BE POSTED AT THEIR SAGEEP BOOTH FOR YEARS TO COME, SO THAT INDIVIDUAL MEMBERS CAN EXPRESS THEIR GRATITUDE FOR THE SUPPORT.

CORPORATE CONTRIBUTION TOTAL: ____________________

PAYMENT INFORMATION

SUBTOTALS:

MEMBERSHIP: $ ____________________

FOUNDATION CONTRIBUTIONS: $ ____________________

TOTAL: $ ____________________

☐ CHECK/MONEY ORDER ☐ VISA ☐ MASTERCARD ☐ AMEX ☐ DISCOVER

CARD NUMBER EXP. DATE

NAME ON CARD

SIGNATURE

MAKE YOUR CHECK OR MONEY ORDER IN **US DOLLARS** PAYABLE TO: EEGS. CHECKS FROM CANADIAN BANK ACCOUNTS MUST BE DRAWN ON BANKS WITH US AFFILIATIONS (EXAMPLE: CHECKS FROM CANADIAN CREDIT SUISSE BANKS ARE PAYABLE THROUGH CREDIT SUISSE NEW YORK, USA). **CHECKS MUST BE DRAWN ON US BANKS.**

PAYMENTS ARE NOT TAX DEDUCTIBLE AS CHARITABLE CONTRIBUTIONS ALTHOUGH THEY MAY BE DEDUCTIBLE AS A BUSINESS EXPENSE. CONSULT YOUR TAX ADVISOR.

RETURN THIS FORM WITH PAYMENT TO: EEGS, 1720 SOUTH BELLAIRE STREET, SUITE 110, DENVER, CO 80222 USA

CREDIT CARD PAYMENTS CAN BE FAXED TO EEGS AT 011.1.303.820.3844

Environmental and Engineering Geophysical Society

1720 South Bellaire Street | Suite 110 | Denver, CO 80222-4303
(p) 011.1.303.531.7517 | (f) 011.1.303.820.3844 | staff@eegs.org | www.eegs.org

Membership Application
Developing World Category Qualification

If you reside in one of the countries listed below, you are eligible for EEGS's Developing World membership category rate of $50.00 (or $100.00 if you would like the printed, quarterly *Journal of Environmental & Engineering Geophysics* mailed to you—to receive a printed *JEEG* as a benefit of membership, select the Developing World Printed membership category on the membership application form):

Afghanistan
Albania
Algeria
Angola
Armenia
Azerbaijan
Bangladesh
Belize
Benin
Bhutan
Bolivia
Burkina Faso
Burundi
Cambodia
Cameroon
Cape Verde
Central African Republic
Chad
China
Comoros
Congo, Dem. Rep.
Congo, Rep.
Djibouti
Ecuador
Egypt
El Salvador
Eritrea
Ethiopia
Gambia
Georgia
Ghana
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
India
Indonesia
Iran
Iraq
Ivory Coast
Jordan
Kenya
Kiribati
Kosovo
Kyrgyz Republic
Lao PDR
Lesotho
Liberia
Madagascar
Malawi
Maldives
Mali
Marshall Islands
Mauritania
Micronesia
Moldova
Mongolia
Morocco
Mozambique
Myanmar
Nepal
Nicaragua
Niger
Nigeria
North Korea
Pakistan
Papua New Guinea
Paraguay
Philippines
Rwanda
Samoa
Sao Tome and Principe
Senegal
Sierra Leone
Solomon Islands
Somalia
Sri Lanka
Sudan
Suriname
Swaziland
Syria
Taiwan
Tajikistan
Tanzania
Thailand
Timor-Leste
Togo
Tonga
Tunisia
Turkmenistan
Uganda
Ukraine
Uzbekistan
Vanuatu
Vietnam
West Bank and Gaza
Yemen
Zambia
Zimbabwe

EEGS Corporate Members

Corporate Benefactor

Your Company Here!

Corporate Partner

Your Company Here!

Corporate Associate

ABEM Instrument AB
www.abem.com

Advanced Geosciences, Inc.
www.agiusa.com

Allied Associates Geophysical Ltd.
www.allied-associates.co.uk

Exploration Instruments LLC
www.expins.com

Foerster Instruments Inc.
www.foerstergroup.com

GEM Advanced Magnetometers
www.gemsys.ca

Geogiga Technology Corporation
www.geogiga.com

Geomar Software Inc.
www.geomar.com

Geometrics, Inc.
www.geometrics.com

Geonics Ltd.
www.geonics.com

Geophysical Survey Systems, Inc.
www.geophysical.com

Geostuff / Wireless Seismic Inc.
www.georadar.com

GISCO
www.giscogeo.com

hydroGEOPHYSICS, Inc.
www.hydrogeophysics.com

Interpex Ltd.
www.interpex.com

MALA GeoScience
www.malags.com

Mount Sopris Instruments
www.mountsopris.com

R. T. Clark Co. Inc.
www.rtclarck.com

Scintrex
www.scintrexltd.com

Sensors & Software, Inc.
www.sensoft.ca

USGS
www.usgs.gov

Zonge Engineering & Research Org., Inc.
www.zonge.com

Zonge Geosciences
www.zonge.com

Corporate Donor

Fugro Airborne Surveys
www.fugroairborne.com

Geomatrix Earth Science Ltd.
www.georentals.co.uk

Intelligent Resources, Inc.
www.rayfract.com

Northwest Geophysics
www.northwestgeophysics.com

Spotlight Geophysical Services
www.spotlightgeo.com

Environmental and Engineering Geophysical Society

2009 Publications Order Form

ALL ORDERS ARE PREPAY

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

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.

Sold To:
Name: ____________________
Company: ____________________
Address: ____________________
City/State/Zip: ____________________
Country: __________ Phone: __________
E-mail: __________ Fax: __________

Ship To (If different from "Sold To":
Name: ____________________
Company: ____________________
Address: ____________________
City/State/Zip: ____________________
Country: __________ Phone: __________
E-mail: __________ Fax: __________

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

SAGEEP PROCEEDINGS

Member/Non-Member

	0026	2009 (CD-ROM)	$75	$100
	0025	2008 (CD-ROM)	$75	$100
	0023	2007 (CD-ROM)	$75	$100
	0020	2006 (CD-ROM)	$75	$100
	0018	2005 (CD-ROM)	$75	$100
	0016	2004 (CD-ROM)	$75	$100
	0015	2003 (CD-ROM)	$75	$100
	0014	2002 (CD-ROM)	$75	$100
	0013	2001 (CD-ROM)	$75	$100
	0012	1988-2000 (CD-ROM)	$150	$225
		SUBTOTAL—PROCEEDINGS ORDERED:		

SAGEEP Short Course Handbooks

	0027	NEW 2009 - Principles and Applications of Seismic Refraction Tomography (Printed Course Notes & CD-ROM) - William Doll	$125	$150
	0028	NEW 2009 - Principles and Applications of Seismic Refraction Tomography (CD-ROM including PDF format Course Notes) - William Doll	$70	$90
	0007	2002 - UXO 101 - An Introduction to Unexploded Ordnance - (Dwain Butler, Roger Young, William Veith)	$15	$25
	0009	2001 - Applications of Geophysics in Geotechnical and Environmental Engineering (HANDBOOK ONLY) - John Greenhouse	$25	$35
	0011	2001 - Applications of Geophysics in Environmental Investigations (CD-ROM ONLY) - John Greenhouse	$80	$105
	0010	2001- Applications of Geophysics in Geotechnical and Environmental Engineering (HANDBOOK) & Applications of Geophysics in Environmental Investigations (CD-ROM) - John Greenhouse	$100	$125
	0004	1998 - Global Positioning System (GPS): Theory and Practice - John D. Bossler & Dorota A. Brzezinska	$10	$15
	0003	1998 - Introduction to Environmental & Engineering Geophysics - Roelof Versteeg	$10	$15
	0002	1998 - Near Surface Seismology - Don Steeples	$10	$15
	0001	1998 - Nondestructive Testing (NDT) - Larry Olson	$10	$15
	0005	1997 - An Introduction to Near-Surface and Environmental Geophysical Methods and Applications - Roelof Versteeg	$10	$15
	0006	1996 - Introduction to Geophysical Techniques and their Applications for Engineers and Project Managers - Richard Benson & Lynn Yuhr	$10	$15

Miscellaneous Items

	0021	Geophysics Applied to Contaminant Studies: Papers Presented at SAGEEP from 1988-2006 (CD-ROM)	$50	$75
	0022	Application of Geophysical Methods to Engineering and Environmental Problems - Produced by SEGJ	$35	$45
	0019	Near Surface Geophysics - 2005 Dwain K. Butler, Ed.; Hardcover Special student rate - 71.20	$89	$139
	0024	Ultimate Periodic Chart - Produced by Mineral Information Institute	$20	$25
	0008	MATLAB Made Easy - Limited Availability	$70	$95
		SUBTOTAL—SHORT COURSE/MISC. ORDERED ITEMS:		

Publications Order Form (Page Two)

Journal of Environmental and Engineer Geophysics (JEEG) Back Issue Order Information:

Member Rate: $15

Non-Member Rate: $25

Qt.	Year	Issue
	1995	
		JEEG 0/1 - July
	1996	
		JEEG 0/2 - January
		JEEG 1/1 - April
		JEEG 1/2 - August
		JEEG 1/3 - December
	1998	
		JEEG 3/2 - June
		JEEG 3/3 - September
		JEEG 3/4 - December
	1999	
		JEEG 4/1 – March
		JEEG 4/2 - June
		JEEG 4/3 - September
		JEEG 4/4 - December
	2000	
		JEEG 5/3 - September
		JEEG 5/4 - December

Qt.	Year	Issue
	2001	
		JEEG 6/1 - March
		JEEG 6/3 - September
		JEEG 6/4 - December
	2003	
		JEEG 8/1- March
		JEEG 8/2 - June
		JEEG 8/3 - September
		JEEG 8/4 - December
	2004	
		JEEG 9/1- March
		JEEG 9/2 - June
		JEEG 9/3 - September
		JEEG 9/4 - December
	2005	
		JEEG 10/1 - March
		JEEG 10/2 - June
		JEEG 10/3 - September
		JEEG 10/4 - December

Qt.	Year	Issue
	2006	
		JEEG 11/1 - March
		JEEG 11/2 - June
		JEEG 11/3 - September
		JEEG 11/4 - December
	2007	
		JEEG 12/1 - March
		JEEG 12/2 - June
		JEEG 12/3 - September
		JEEG 12/4 - December
	2008	
		JEEG 13/1 - March
		JEEG 13/2 - June
		JEEG 13/3 - September
		JEEG 13/4 - December
	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:	

Payment Information:

☐ Check #: ______________________________ (Payable to EEGS)

☐ Purchase Order: ______________________________

(Shipment will be made upon receipt of payment.)

☐ Visa ☐ MasterCard ☐ AMEX ☐ Discover

Three easy ways to order:

Fax to: 303.820.3844

Internet: www.eegs.org

Mail to: EEGS
1720 S. Bellaire St., #110
Denver, CO 80222-4303

Email: staff@eegs.org

Card Number: ______________________________

Cardholder Name (Print): ______________________________

Exp. Date: ______________________________

Signature: ______________________________

Environmental and Engineering Geophysical Society

2009 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: ____

THANK YOU FOR YOUR ORDER!

EEGS/Forms/Merchandise Order Form/2009 Prices and details on this form are as accurate as possible, but are subject to change without notice.