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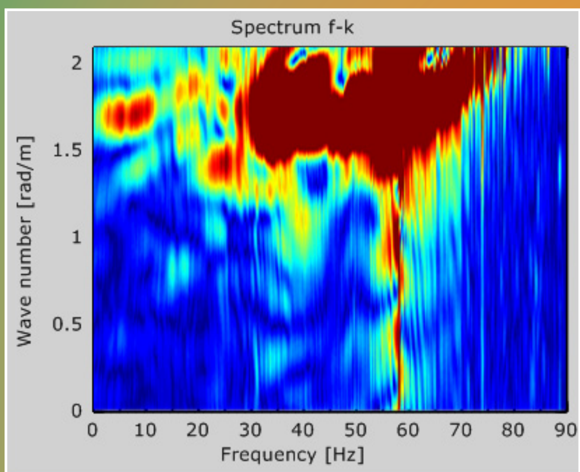
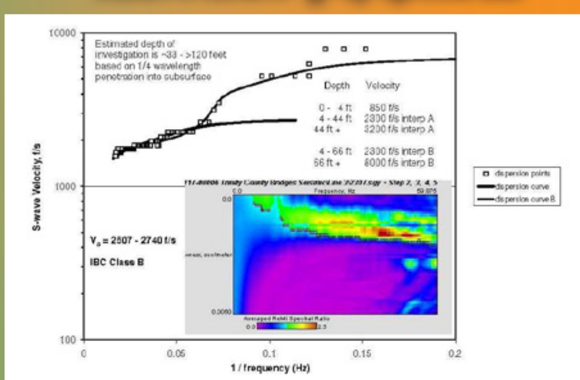
www.eegs.org

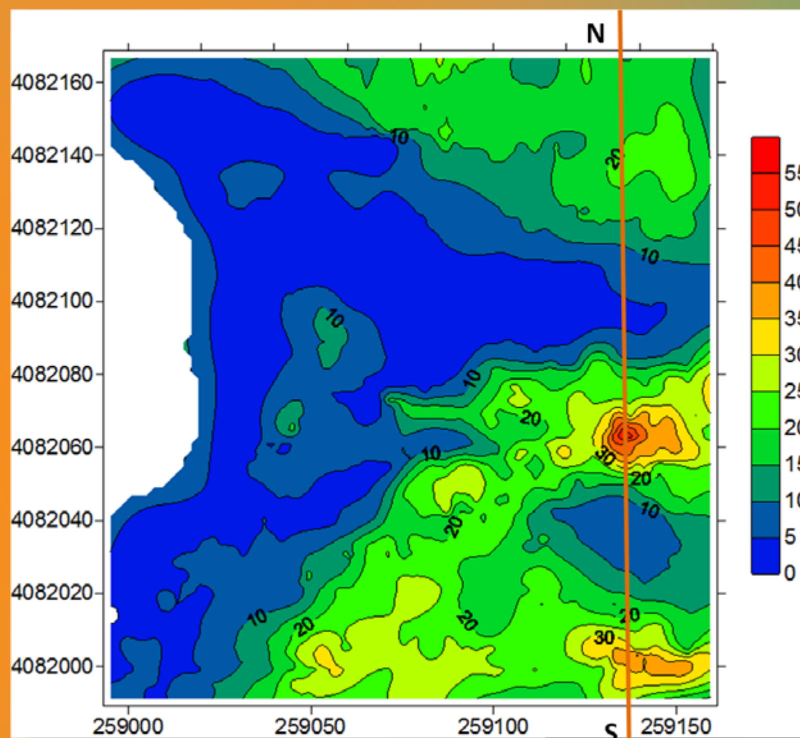
Near-Surface Geophysical Investigations



Active MASW (f-k) Spectrum



Shallow & Deep ReMi™ Interpretation



Ground Conductivity at 45,030Hz

Also in this issue . . .

- NSG Best Usages & Limitations Survey
- Special Edition of JEEG
- Industry News: New NMR Logging Tool
- SAGEEP 2011 Online Abstract Submission

. . . and more!

EEGS Website Gets a Facelift

On the Cover

This issue features geophysical techniques for investigating near surface features and environmental applications. **Upper left:** Frequency-wavenumber spectrum from an active MASW survey. **Lower left:** Two alternative ReMi™ interpretations of a seismic line based on shallow and all data with a frequency above 6 Hz. **Right:** Variations in ground conductivity at a carbon sequestration pilot site in the north-central part of the San Juan basin.

What We Want From You

The ***FastTIMES*** editorial team welcomes contributions of any subject touching upon geophysics. The theme for our next issue is advances in the application of geophysical techniques to optimize processes in agricultural engineering. ***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 November 30, 2010 to ensure inclusion in the next issue. We look forward to seeing your work in our pages.

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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.

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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.

Calendar

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

2010

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 for the special issue of JEEG on Geophysics for Levee Safety
February 28	Deadline for submission of articles, advertisements, and contributions to the March issue of *FastTIMES*
April 10–14	SAGEEP 2011: Symposium on the Application of Geophysics to Environmental and Engineering Problems, Charleston, SC
May 23–26	73rd EAGE Conference & Exhibition: Unconventional Resources and the Role of Technology, Vienna, Austria
May 31	Deadline for submission of articles, advertisements, and contributions to the June issue of *FastTIMES*
June 22–24	International Workshop on Advanced Ground Penetrating Radar 2011: presents a wide range of scientific and technical information of high standard to scientists, engineers and end-users of GPR technology. Aachen, Germany
June 28–July 7	IUGG General Assembly: International Union of Geodesy and Geophysics (IUGG) General Assembly invites researchers world-wide to participate in an exciting, multi-disciplinary conference on cutting edge science, Melbourne, Australia
August 31	Deadline for submission of articles, advertisements, and contributions to the September issue of *FastTIMES*

President's Message: Recent Activities

John Stowell, President (john.stowell@mountsopris.com)

The 2010 EAGE - Near Surface Division technical conference was held in early September in Zurich, Switzerland. Once again, four of the top ten papers presented at SAGEEP 2010 were showcased in a special session. Our representatives did an excellent job and fielded questions from a diverse group of geoscientists from Europe, Africa, and Asia. Through this annual exchange program, both societies benefit from the cross-pollination of ideas from a truly global geographic sampling.

In late September, the AEG held its annual meeting in Charleston, South Carolina. Many of our corporate members exhibited at this meeting, and I had the privilege to assist in the presentation of a short course on Rock Core Description for Engineering and Environmental Purposes. It also offered an opportunity for me to visit the site of our 2011 SAGEEP conference. Charleston is a fascinating city, with a remarkable history, and the conference center we have chosen for our meeting, situated on the Ashley River, should make this a SAGEEP not to be missed.

The SAGEEP 2011 technical program is nearly complete. Technical Chair Greg Baker has been very pleased with the results from his "call for sessions" proposal. Thanks go out to those of you who have suggested and offered to lead the many new and interesting sessions planned for this meeting.

The abstract submission site will be open by the time you read this, with the deadline set for November 19th. Be sure to review the new requirements for abstracts, which have been modified from prior years, to make the process simpler.

In mid-October your board convened in Denver for our semi-annual 2 day meeting. This event was scheduled in Denver to coincide with the annual SEG conference and exposition. This allowed convenient interaction with our sister organization, SEG-Near Surface. During our meeting we met with SEG executive vice-President John Bradford to discuss our revised memorandum of understanding, collaboration with SEG for future events, and a co-publication agreement for a new book, Advances in Near-Surface Seismology and Ground Penetrating Radar. AGU, SEG, and EEGS will share in costs and revenues from this interesting compendium of the latest techniques in these fields.

During the board meeting, several critical areas were discussed, including membership, committees, and our plans for the next several years. The EEGS Foundation presented us with their vision and goals, and we are pleased to see this closely related entity now ready to identify and accept funding for the promotion of near surface geophysics. Go to the EEGS website to open a link which describes the foundation in more detail.

Following the board meeting, several board members took part in SEG near-surface activities, including a signing ceremony to mark the acceptance of our new MOU, as well as the SEG-NS business meeting.

In addition, your board was represented at the Geophysicists without Borders program meeting, and the SEG foundation meeting. The SEG-NS held its annual social event at the Wynkoop Brewing Company, where John Bradford was presented with the Harold Mooney Award, and Peter Annan received a lifetime membership.

From the Editor's Desk

Moe Momayez, Editor-in-Chief (moe.momayez@arizona.edu)

This is an exciting time at EEGS. New partnerships are being forged with sister societies. We have a new associate editor at *FastTIMES*. And, our website is getting much more than a facelift.

First, let me tell you about the website. Although the new layout and content may not be deployed by the time this issue of *FastTIMES* is published, we are running on a much more powerful engine since the call for the SAGEEP 2011 online abstract submission went out at the end of October. Our website was out-of-date in many ways and too clunky for even small updates. At the pre SAGEEP 2010 retreat, the EEGS board approved a motion to revamp the entire website and implement an advanced content management system and framework. This means that we are able to create new sections and modify old ones on a short notice. Content can now be updated regularly. The website includes a 'Downloads' area where geophysical data, and free and open source software will be made available to EEGS members, and an 'Education' area containing informative materials related to near-surface geophysical techniques, applications, webinars and short courses. We are seeking more active contributors to share data, algorithms, program code, short notes and time saving tips with the near-surface geophysics community.

EEGS welcomes Dr. Barry Allred as the new *FastTIMES* Associate Editor. Barry is well-known in the near-surface community for his contributions to the field of agricultural geophysics. He was the lead editor of the first book focused specifically on agricultural geophysics (*Handbook of Agricultural Geophysics*). Barry is an Agricultural Engineer with USDA's Agricultural Research Service in Columbus, Ohio. He is also an Adjunct Professor in the Food, Agricultural, and Biological Engineering Department at Ohio State University. The next issue of *FastTIMES* presents advances in the application of geophyscal techniques to improve agricultural processes and Barry has taken the lead in preparing the content.

At this year's SEG meeting, a memorandum of understanding between EEGS and SEG was signed, opening the way to a multitude of collaborative efforts around organizing joint conferences, projects, and publications. Negotiations are underway with other geophysics societies to create alliances that would extend benefits to members, expand the membership base and organize joint meetings. We will bring you more details in the next issue.

In the midst of all these exciting developments and future directions of EEGS, it goes without saying that this year the virtual pages of *FastTIMES* were packed with cutting edge research and all the best in geophysics. We are always seeking new articles, reviews and scientific papers. Share your work with us and make this the issue that you get involved!

Sponsorship Opportunities

There are always sponsorship opportunities available for government agencies, corporations, and individuals who wish to help support EEGS's activities. Specific opportunities include development and maintenance of an online system for accessing SAGEEP papers from the EEGS web site and support for the 2011 SAGEEP conference to be held in Charleston, South Carolina. Contact John Stowell (john.stowell@mountsopris.com) for more information.

Environmental and Engineering Geophysical Society

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.

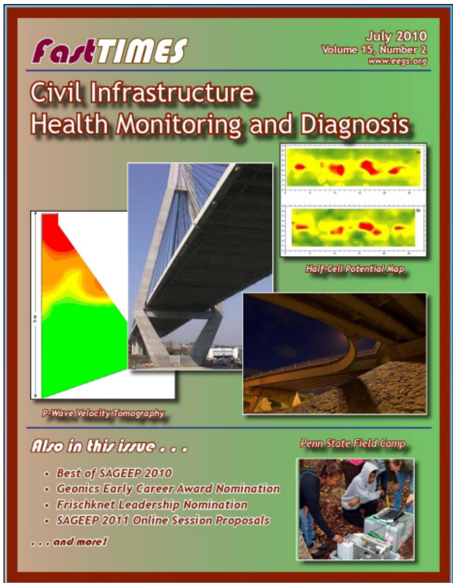
Descriptions of all the new membership options are outlined on EEGS' web site (www.eegs.org) in the membership section.

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 (July 2010, cover image at left) has been downloaded more than 25,000 times as of October 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.

EEGS Foundation makes great strides in its first years.

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

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

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The JEEG Page

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

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Revised Ground-Penetrating Radar Soil Suitability Maps
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Editor's Scratch

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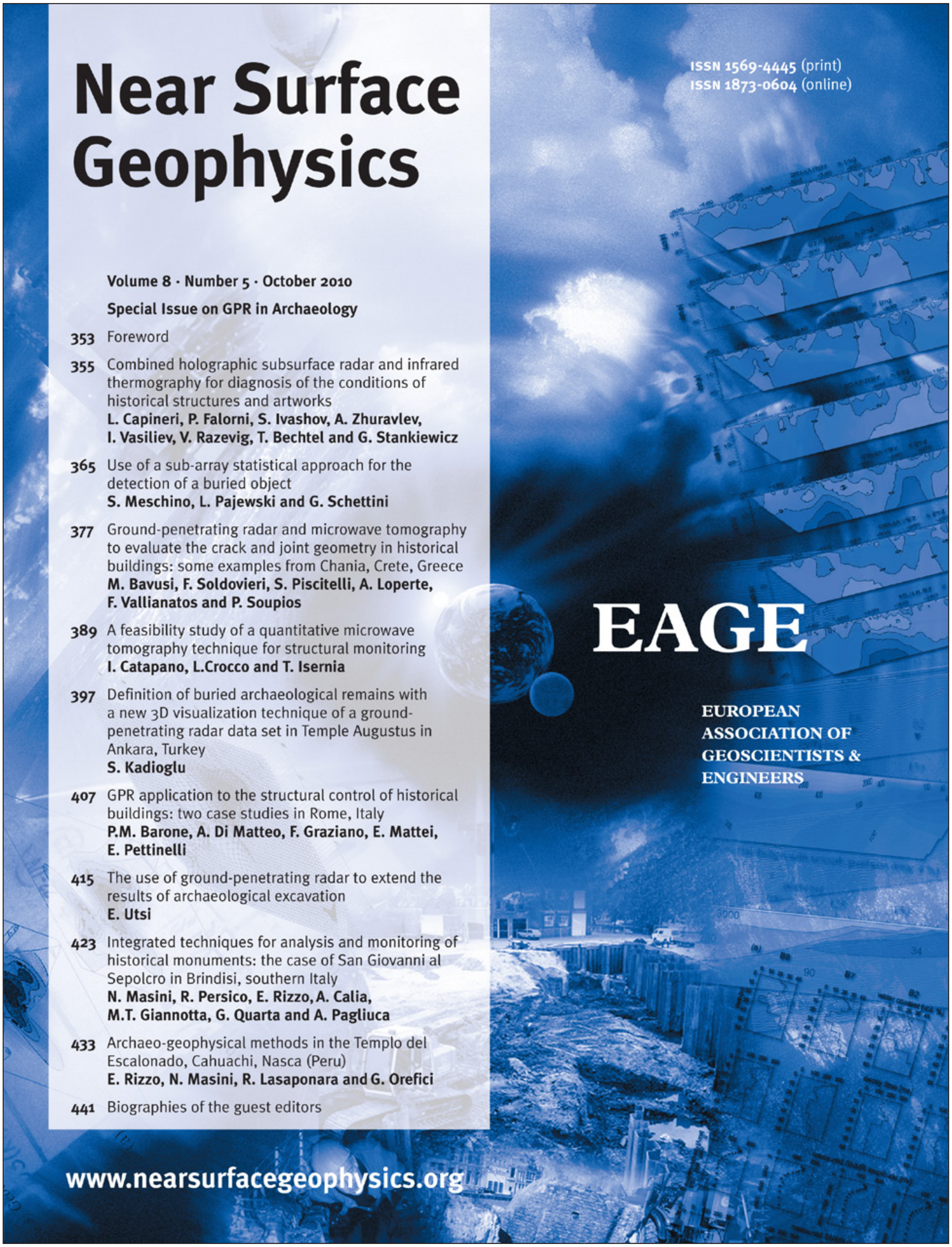
EAGE's Near Surface Geophysics Journal, October 2010

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



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EAGE
EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

www.nearsurfacegeophysics.org

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

Seismic Geotechnical Site Characterization by Means of MASW and ReMi Methods

Vitantonio Roma, Roma & Associati, Turin, Italy (roma.vitantonio@libero.it)

Introduction

The interest of both the scientific community and professionals towards the MASW method (Multichannel Spectral Analysis of Surface Waves) has been increasing in the last years.

The reasons for such an interest are: 1) increased consciousness that the design and understanding of the structures response to dynamic forces (earthquake, wind, vibrations, explosions, etc.) can be achieved only by identifying the dynamic properties and hence by determining the shear wave velocity profile Vs of the sites by means of a properly studied methodology; 2) the need for a relatively easy technique that is sufficiently accurate and would overcome some of the intrinsic drawbacks of alternative techniques of investigation.

Local Seimic Effects and Site Classification

The local seismic classification of a site essentially consists of determining the category to which the site belongs on the basis of the main parameters which influence the site response to earthquakes or more generally to external dynamic forces. There is one italian and several international codes, which classify the sites on the basis of their nature and their geotechnical characteristics, especially based on the vertical shear wave velocity profile Vs.

Italian and European Seismic Codes

The seismic classification provided by the new italian seismic code O.P.C.M. n. 3274/2003 and also by the construction law D.M. 15/09/2005 “Ex Testo Unico sulle costruzioni” has been prepared following the same criteria adopted by the Eurocode 8. As a consequence there exists a satisfactory agreement between the site categories contemplated by the new Italian seismic code and the Eurocode 8 (see Table 1). With the recent update of the law about constructions D.M. 14/01/2008 (see Table 2) some important modifications have been applied to the criteria for classifying the sites of type A, B, C, D, E, S1, S2. Some new conditions have been introduced concerning the thickness of the soil overlaying the bedrock. Hence not only the equivalent shear wave velocity Vs30, but also the thickness of the soil overlaying the bedrock becomes important for seismic site classification.

The Importance of Vs30

The Italian seismic code OPCM 3274, as well as the Eurocode 8 , if specific investigations are not available, determines the seismic design force on the basis of the seismic zone to which the site belongs.

The italian territory has been divided into 4 seismic zones, which are characterized by a peak ground acceleration ag for the site of type A, that is surface rock or very stiff homogeneous soil (see table 1). When dealing with sites of type B, C, D E, S1, S2 the seismic motion at the bedrock generally is different from the seismic motion at the free surface, depending on the intensity and the frequency content of the seismic input, on the thickness and the geotechnical characteristics of the soil overlaying the bedrock. If a specific analysis of wave propagation is not performed at the site, then the spectral seismic acceleration at the free surface can be evaluated by means of a factor S and a spectral shape provided by the seismic code. In the case of sites of type S1 and S2 the seismic code requires a specific analysis of the local seismic effects.

For the other types of site the classification is defined by means of the equivalent vertical shear wave velocity Vs30 within the first significant 30m of the site:

$$V_{S30} = \frac{30}{\sum_{i}^{n} \left(\frac{h_i}{[V_s]_i} \right)} \quad (1)$$

where Vs_i and h_i are the vertical shear wave velocity and the thickness of the i-th layer of the soil over the bedrock.

Seismic Site Classification by Means of the MASW Method

The MASW method is a non-invasive investigation technique (there is no need of boreholes), which allows to determine the vertical shear wave velocity Vs by measuring the propagation of the surface waves at several sensors (accelerometers or geophones) on the free surface of the site.

The main contribution to the surface waves is given by the Rayleigh waves, which travel through the upper part of the site at a speed, which is correlated to the stiffness of the ground.

In a layered soil Rayleigh waves are dispersive, that is Rayleigh waves with different wave length travel with a different speed (both phase and group velocities) (Achenbach, J.D., 1999, Aki, K. and Richards, P.G., 1980). Dispersion means that the apparent or effective phase (or group) velocity depends on the propagating frequency. This circumstance implies that high frequency waves with relatively short wave lengths contain information about the upper part of the site instead low frequency waves with longer wave lengths provide information about the deeper layers of the site.

The MASW method can be applied as the active method or the passive method (Zywicki, D.J. 1999) or a combination of both active and passive. In the active method the surface waves are generated by a source located at a point on the free surface and then the wave motion is measured along a linear array of sensors. In the passive method the sensors can be located in arrays of different geometric shape: linear, circular, triangle, square, L shape, and the source is represented by the environmental noise, whose direction is not known a priori. The active method generally allows to determine an experimental apparent phase velocity (or dispersion curve) within the frequency range 5Hz -70Hz Hence the active method can give information concerning the first 30m-35m, depending on the stiffness of the site. The passive method generally allows to define an experimental apparent phase velocity (or dispersion curve) within the frequency range 5Hz -15Hz Hence the passive method can generally provide information about deeper layers, below 50m, depending on the stiffness of the site.

In the following both the active and the passive MASW methods will be explained and the combination of both will be applied to a real case. As passive method the ReMi procedure (Refraction Microtremors) will be used, since the results provided by the passive MASW and ReMi are equivalent.

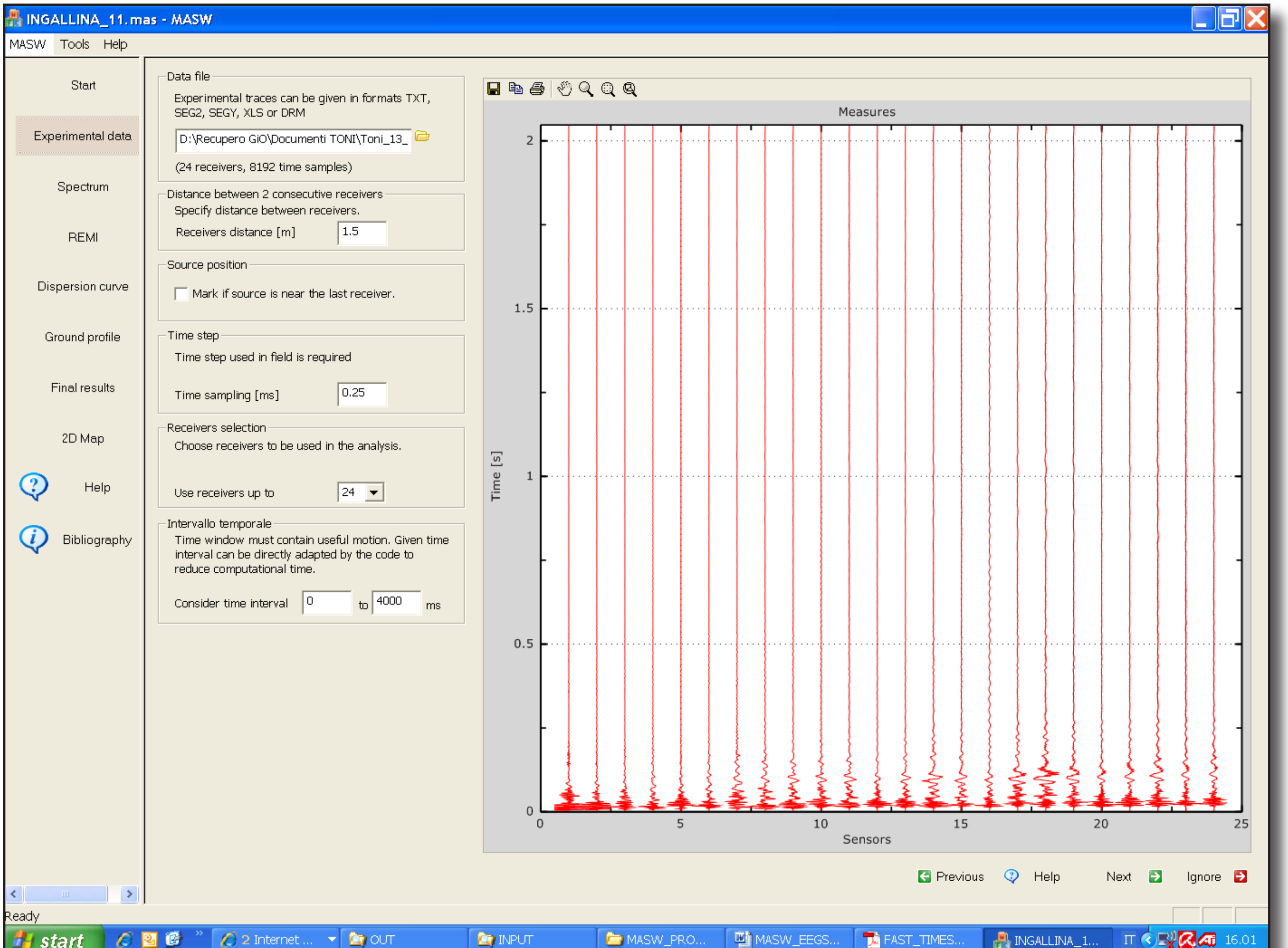


Figure 1. Vertical wave motion (hammer source) for the active MASW.

The MASW method consists of three steps (Roma, 2002): (1) in the first step the experimental apparent phase velocity (or dispersion curve) is determined (Figure 2), (2) in the second step the numerical-theoretical apparent phase velocity (or dispersion curve) is calculated (Figure 5), (3) in the last step the vertical shear wave velocity profile Vs is determined, by properly modifying the thickness h, the shear Vs and compressional Vp wave velocities (or in alternative to Vp it is possible to modify the Poisson's parameter ν), the mass density ρ of all the layers considered in the site model, until the optimal match between the experimental and the theoretical dispersion curves is achieved (Figure 5). During step 3 the site model, the shear wave velocity profile can be determined by means of a trial and error or an automatic procedures, or a combination of both. Usually the number of layers, the Poisson's parameter ν and the mass density ρ are assigned and successively the thickness and the shear wave velocity of the layers are modified. After the shear wave velocity profile has been determined, then the equivalent Vs30 can be calculated and hence the seismic class of the site can be established (Figure 6).

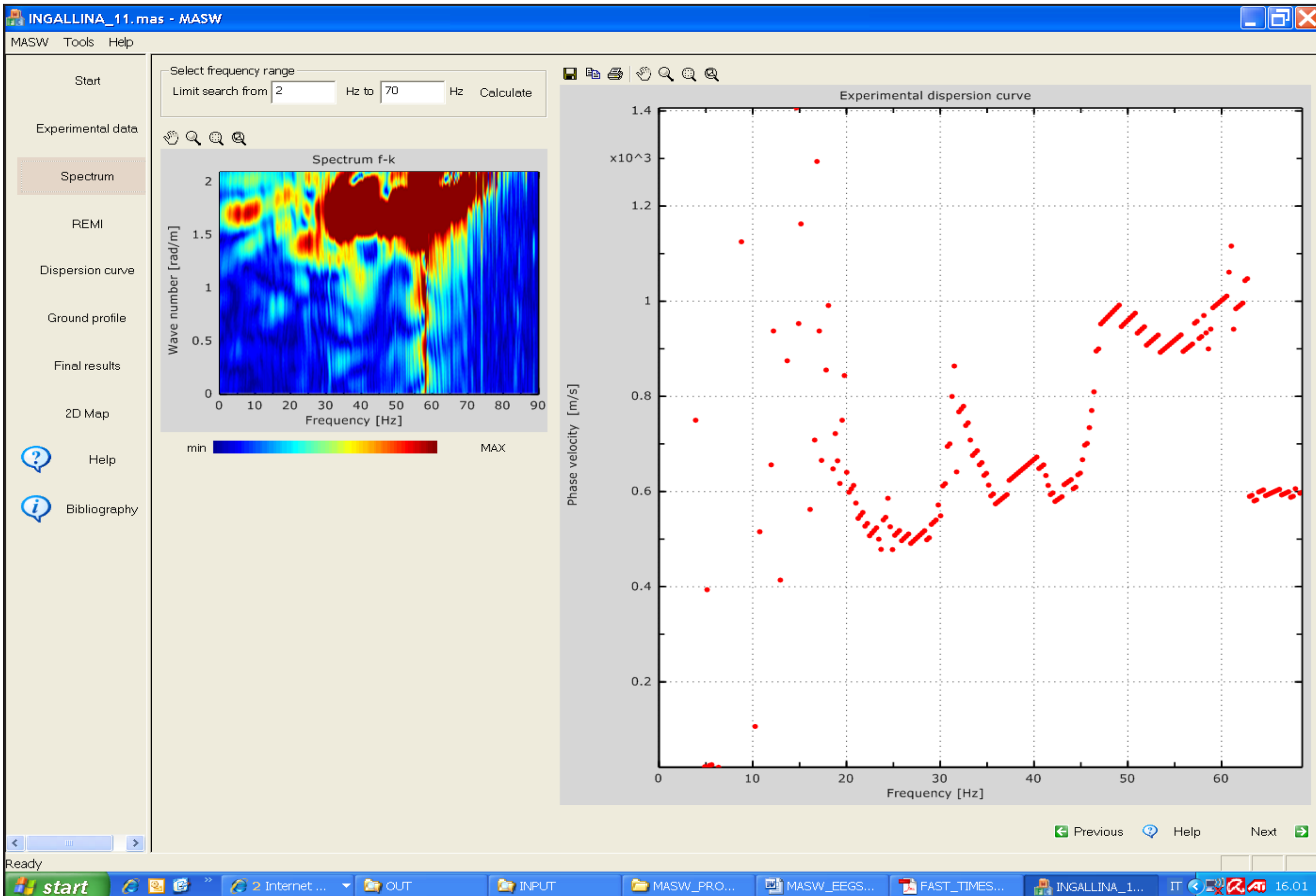


Figure 2. (f-k) spectrum and experimental dispersion curve with active MASW.

It is meaningful to acquire any additional information about the geotechnical nature of the site, so that the existence of the special sites of type S1 and S2 can be recognized.

Theoretical Background of the MASW Method

The MASW method is based on the measurement and analysis of Rayleigh waves propagating through a layered half-space.

Dispersion and Attenuation of Rayleigh Waves

The existence of propagating of the Rayleigh waves into a layered half-space is searched by setting to zero the Rayleigh dispersion relation R(f,k). The Rayleigh dispersion relation correlates the geometric and mechanical properties of the n layers of the layered half-space with the frequency f and the wave number k:

$$R(Vs_i, h_i, \nu_i, \rho_i, k, f) = 0, \quad i = 1 \ to \ (n+1) \tag{2}$$

More details can be found in Roma, V. 2007, Roma, V. 2001.

The search of the roots of the equation (2) can be performed by maintaining the frequency at a value f0 and searching the wave numbers k which satisfy the equation (2). For a layered half-space the dispersion relation (2) is multiple value, that is for a given value of frequency more than one wave number k may satisfy the relation (2). Each root of the equation (2), given by a couple of values (f, k) represents a simple wave or mode of Rayleigh, which can propagate through the layered half-space. For a given frequency $\omega 0 = 2\pi f0$, the first mode of Rayleigh, named the fundamental mode, corresponds to the greatest wave number, which satisfies equation (2). The other smaller wave numbers which satisfy equation (2) define the higher modes of Rayleigh. Hence equation (2) for a layered half-space establishes the existence of several modes of Rayleigh, which for an assigned frequency propagate at different phase and group velocities.

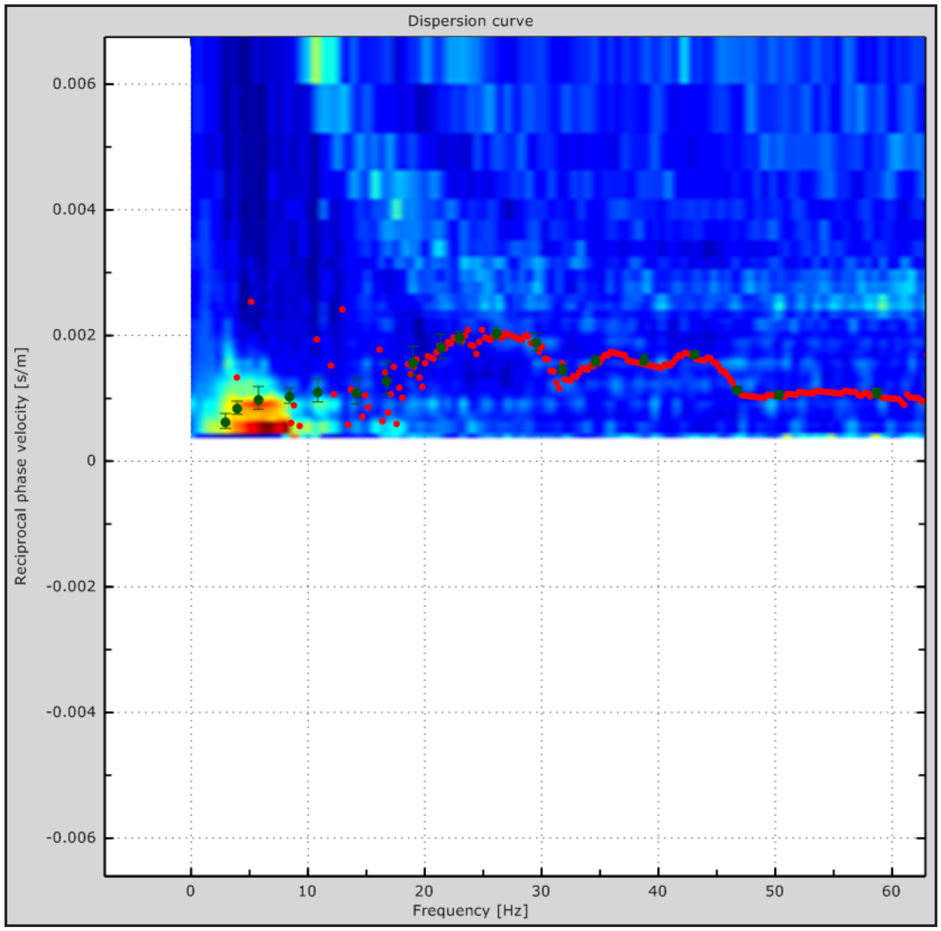


Figure 3. ReMi spectrum together with the active MASW experimental dispersion curve in the (p-f) domain.

The physical interpretation of such a mathematical model is explained by the observation of the dispersion phenomenon, that is during the propagation of a wave train made of several simple Rayleigh waves, the waves separate or disperse with increasing time and distance, since they travel at different velocities (Figure 1).

In addition to the dispersion phenomenon, Rayleigh waves are subject to amplitude loss caused by both geometric and dissipative attenuation. Geometric attenuation is due to the fact that the same energy is distributed over a cylindrical surface, which increases with distance from the source. The dissipative attenuation is caused by energy dissipation when particles oscillate around their equilibrium positions during the wave propagation (Roma V. 2003).

Apparent or Effective Dispersion Curve

The measurement of the surface waves along the sensors on the free surface of the ground gives the wave motion in the time-space domain (Figure 1). The perturbation generated by the point source contains all the several Rayleigh modes (Sv and P waves attenuates after few meters from the point source), which form a whole wave train and cannot be discerned nearby the point source. The dispersion of the Rayleigh modes can be completely observed only at an adequate distance from the point source (this distance is greater than about 100m in practice).

Experimental Dispersion Curve

When the wave field is transformed from the time-space domain into the frequency-wave number or equivalently into the frequency-phase velocity domain in order to show the dispersion relation equation (2), then it is observed that it is not possible to distinguish among the several Rayleigh modes as it is predicted by theory. Instead of the several Rayleigh modes, generally, only a unique apparent, also said effective, dispersion curve is observable (Figure 2). The experimental apparent dispersion curve obtained from the wave motion measured in field is the result of the interaction among all the several modes of Rayleigh, also included the geometric array of sensors used for the measurement. In fact the geometric configuration of the sensors may influence the value of the apparent dispersion curve at certain frequencies (Roma V. 2001,b, Roma V. et al. 2002).

Depending on the geometric (thicknesses) and mechanical (Vs, Vp, ρ) of the ground layers, some modes of Rayleigh can appear as predominant with respect to the other modes at certain frequencies. Usually when the stiffness of the layers increases gradually with depth, then the first or fundamental mode of Rayleigh becomes predominant at every frequency.

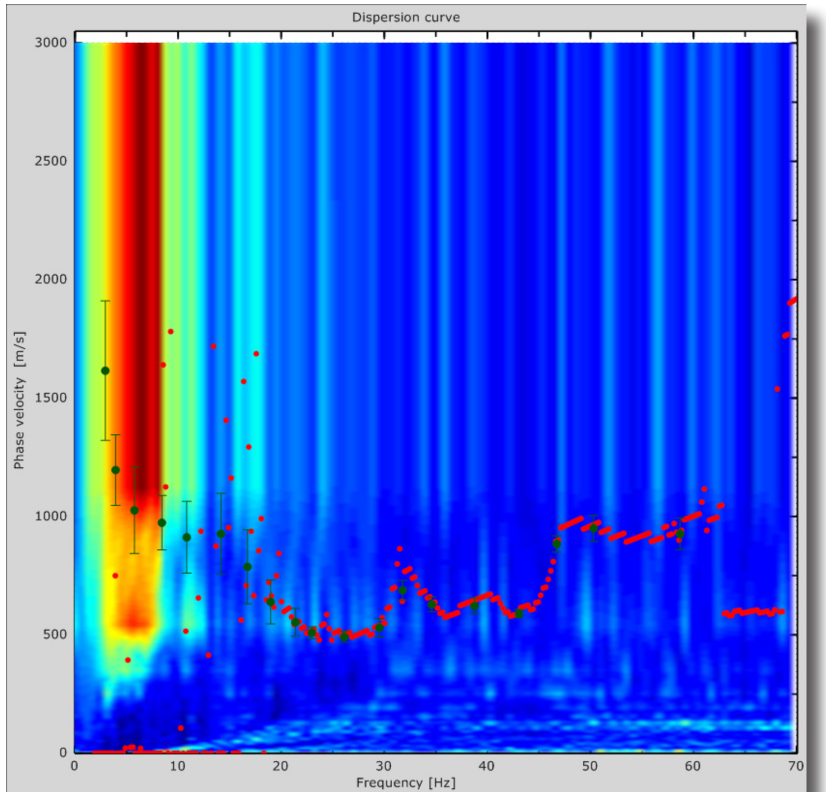


Figure 4. ReMi spectrum together with the active MASW experimental dispersion curve in the (v-f) domain.

Nevertheless several stratigraphies exist with stiff layers trapped between softer layers, or viceversa with soft layers trapped between stiffer layers, or more generally with a strong stiffness contrast between two consecutive layers, where higher modes of Rayleigh become predominant at certain frequencies. It may occur that at any frequencies there is not predominance of a unique mode, but two or more modes have the same energy. Under these conditions the apparent dispersion curve does not coincide with any mode of Rayleigh, since the apparent dispersion curve is the combination of all the predominant modes.

Theoretical-Numerical Dispersion Curve

The theoretical apparent or effective dispersion curve can be calculated once the modes of Rayleigh have been determined (Figure 4). To reach this purpose several methods exist, such as the Roma's method and the Lai and Rix method (Roma V. 2001b, Roma V. 2007b).

It can be demonstrated that the theoretical apparent dispersion curve determined by the Roma's procedure coincides with the theoretical effective dispersion curve determined by Lai and Rix procedure, if proper conditions about the smoothness of the dispersion curve are respected (Roma V. 2000, Roma V. 2007b).

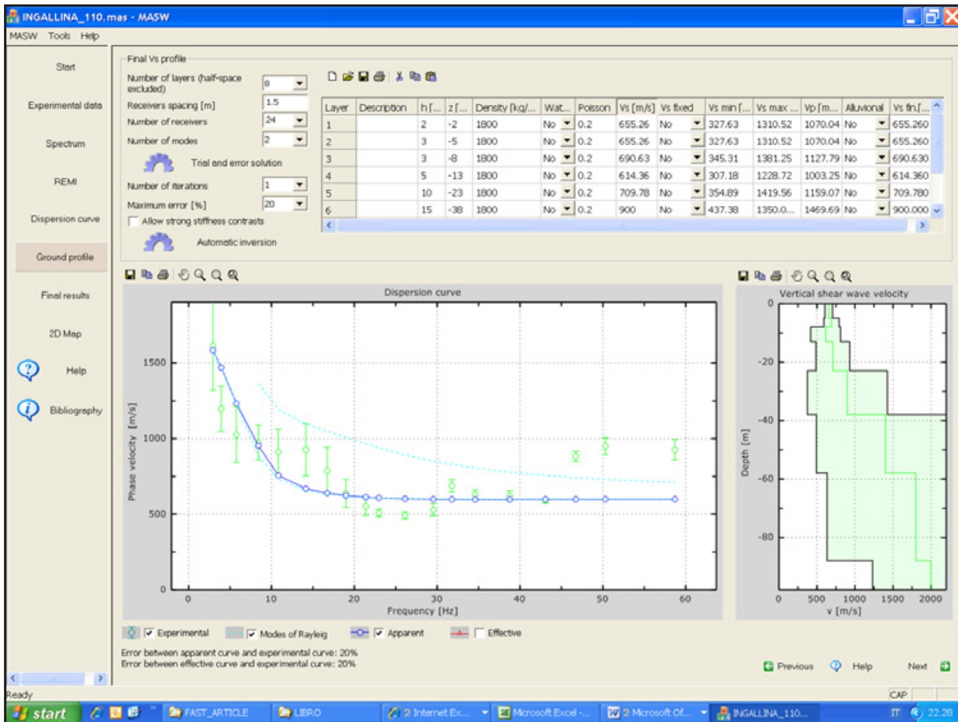


Figure 5. Numerical and experimental dispersion curves (left side) and final shear wave velocity profile Vs.

The theoretical apparent dispersion curve determined by Roma's procedure is calculated in the same manner followed in determining the experimental dispersion curve. The only diversity concerns the way in which the spectrum (f-k) of the wave field is obtained. The experimental (f-k) spectrum is obtained by a 2D Fourier transform of the time-space wave field, instead the numerical (f-k) spectrum is obtained by only 1D Fourier transform, applied to the Green's function of the layered half-space. The Roma's procedure allows to consider the contribution of all higher modes for estimating the apparent dispersion curve. The contribution of all higher modes becomes relevant for inversely dispersive sites, where softer layers are trapped between stiffer layers or where stiffer layers are trapped between softer layers.

Alternatively the numerical apparent dispersion curve can be determined using the Lai and Rix procedure (Lai, 1998). It is based on the concept that the wave train of all the modes of Rayleigh can be considered as a unique complex perturbation, where all the modes of Rayleigh form a unique wave phase.

ReMi Method

The ReMi (Refraction Microtremors) method has been developed by Louie (Louie, 2001). It consists of three steps, the same as the MASW method: the first step concerns the determination of the experimental dispersion curve of Rayleigh waves; the second step coincides with the calculation of the numerical apparent dispersion curve and the third step consists of inverting the apparent dispersion curve in order to find the vertical shear wave profile of the site.

In the ReMi method, the experimental dispersion curve is obtained by transforming the (t-x) domain gathered on site to the (p-f) domain by means of a p-tau transformation followed by a Fourier transform. Following the steps given by Louie (Louie, 2001) the p-tau transformation can be written as:

$$A(p, tau) = \int_x A(x, t = tau + px)\, dx \tag{3}$$

where the slope of the line p = dt/dx is the inverse of the apparent velocity Va in the x direction. Next, the complex Fourier transform of every p-tau trace in the tau (intercept time direction) is computed:

$$F_A(p,f) = \int_x A(p, tau)\, e^{-2i\pi f tau}\, dtau \tag{4}$$

The power spectrum S(p,f) is the magnitude squared of the complex Fourier transform:

$$S_A(p,f) = F_A^*(p,f) \cdot F_A(p,f) \quad (5)$$

where the * denotes the complex conjugate. This completes the transform of a record from distance-time (x-t) into p-frequency (p-f) space.

The ray parameter p for these records is the horizontal component of slowness (inverse velocity) along the array. This means that once the spectrum and the experimental dispersion curve in the (p-f) domain have been evaluated, then it is straightforward to calculate the experimental dispersion curve in the (v-f) domain.

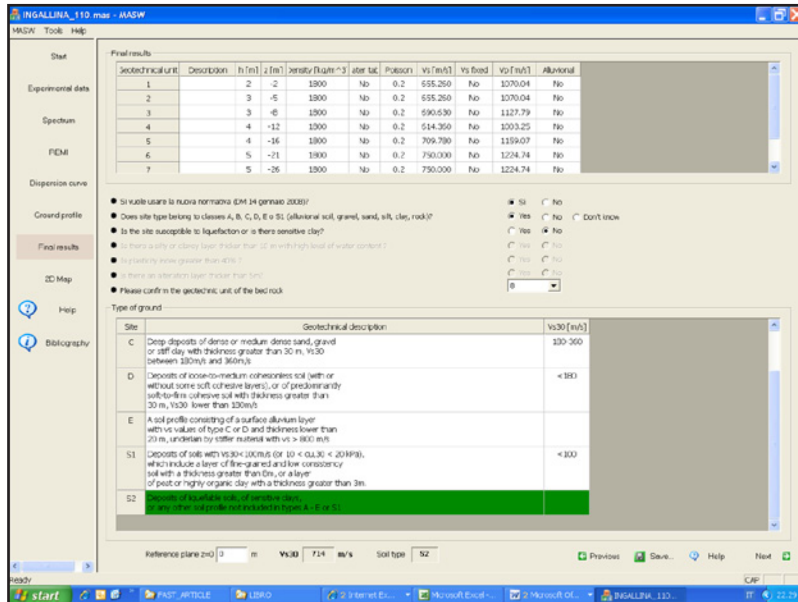


Figure 6. Site seismic classification based on Vs30.

Picking the Experimental Dispersion Curve

In his article Louie explains that the experimental dispersion curve should be obtained from the spectrum in the (p-f) domain by picking not the maxima of the spectrum, but the lower edge of the lowest-velocity, but still reasonable peak ratio. He says that the reason for such a procedure is that the arrays are linear and do not record an on-line triggered source, so some noise energy will arrive obliquely and appear on the slowness-frequency images as peaks at apparent velocities Va higher than the real in-line phase velocity v:

$$V_a = v/\cos(a) = 1/p \quad (6)$$

$$a = \cos^{-1}(v \times p) \quad (7)$$

where ‘a’ is the propagation angle off the line direction.

Louie also mentions that picking the lower bound of the spectrum will exclude noise and higher modes of Rayleigh, hence only the fundamental mode of Rayleigh will form the experimental dispersion curve. It is also said that if it is known that the source direction aligned with the array (i.e. a=0), then the maxima of the spectrum must be picked instead of the lower bound.

In the example shown in the following we have overlapped the experimental dispersion curve obtained with the active MASW method with the spectrum in the (p-f) domain provided by the ReMi method. As it can be observed (Figure 4) the peaks of the MASW (f-k) spectrum coincide better with the maxima of the REMI (v-f) spectrum rather than the lower edge of the spectrum.

Application of Both MASW and ReMi to a Real Case

The active MASW method performed by means of a hammer allows one to obtain information within the frequency range 10-100 Hz; hence it provides information within the first 30m of the site. If a more powerful source is used (truck or a heavy shaker), frequencies lower than 10 Hz and hence depths higher than 30m can be reached. The ReMi (Refraction Microtremors) method allows one to obtain information within the frequency range 1-15 Hz, depending on the available environmental noise; hence it can give information about layers deeper than 30m, potentially down to 100m (Louie, 2001). In this regard, the ReMi method is equivalent to the passive MASW. By combining the information from the active MASW and the ReMi methods, it is possible to cover the whole frequency range of interest in the seismic site characterization 1-100 Hz, reaching depths greater than 30m required by the international codes in order to evaluate the Vs30.

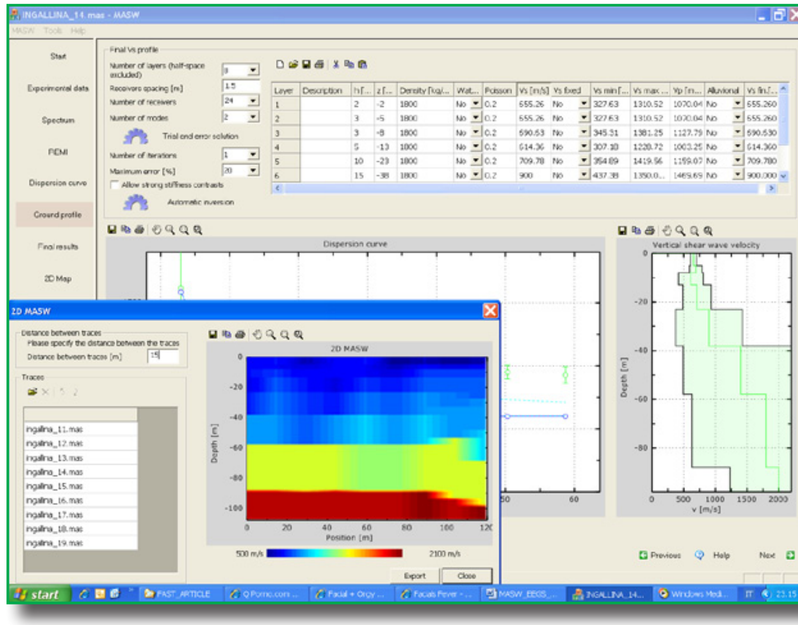


Figure 7. 2D Vs profile by means of a series of MASW-REMI tests.

The study site is located in Taormina, near the Etna Volcano (Sicily, Italy) (Figure 8). Both the active MASW and the ReMi tests were performed. The parameters of the MASW tests are:

- Geophone spacing = 1.5m
- Source type = 8kg hammer
- Delta time = 0.25ms
- Source = 1.5m from first geophone
- Total time = 4 s
- Number of geophones = 24

The data were processed using the MASW software (www.masw.it).

In Figure 1 the time-space vertical wave motion, and in Figure 2 the (f-k) spectrum and the experimental dispersion curve are shown. For the same site the parameters of the ReMi test are:

- Geophone spacing = 5.0m
- Source type = environmental noise
- Delta time of acquisition = 2ms
- Total time of acquisition = 64s
- Number of geophones = 24

Figure 8. Picture of the site.

In Figures 3 and 4 the (p-f) and (f-v) spectrum obtained with the ReMi method are shown together with the experimental dispersion curve calculated with the active MASW method. It can be observed that there is very good complementarity between the MASW and ReMi methods, so that the experimental dispersion curve can be determined in a very large frequency range (3Hz-60Hz).

Figure 5 illustrates the comparison between the experimental and the numerical dispersion curves, with a relative error of 20%. In Figure 5 the final Vs profile is shown, with the shadow zone which represents the associated error of the most probable Vs profile.

According to this Vs profile the Vs30 is equal to 735m/s and following the Eurocode 8 and the OPCM 3274 the site is classified as type B. Following the new Italian code D.M. 15/09/2005 the site type is S2, hence a more detailed seismic analysis is required to evaluate seismic local effects (Figure 6).

By performing a series of 1D MASW-REMI tests, with a spatial shift of 15m, a 2D Vs profile was created (Figure 7).

Table 1. Seismic site classification according to Eurocode 8

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface	> 800	_	_
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of m in thickness, characterised by a gradual increase of mechanical properties with depth	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of m	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with v_s > 800 m/s			
S_1	Deposits consisting – or containing a layer at least 10 m thick – of soft clays/silts with high plasticity index (PI > 40) and high water content	< 100 (indicative)	_	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

Table 2. Seismic site classification according to the new Italian code D.M. 14/01/2008

Soil type	Description	Vs 30 (m/s)
A	Rock or other rock-like geological formation, including at most 3 m of weaker material at the surface	>800
B	Deposits of very dense sand, gravel, or very stiff clay, at least 30 m in thickness, characterized by a gradual increase of mechanical properties with depth, Vs30 between 360m/s and 800m/s	360-800
C	Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness greater than 30 m, Vs30 between 180m/s and 360m/s	180-360
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil with thickness greater than 30 m, Vs30 lower than 180m/s	<180
E	A soil profile consisting of a surface alluvium layer with vs values of type C or D and thickness lower than 20 m, underlain by stiffer material with vs > 800 m/s	<360
S1	Deposits of soils with Vs30<100m/s (or 10 < cu,30 < 20 kPa), which include a layer of fine-grained and low consistency soil with a thickness greater than 8m, or a layer of peat or highly organic clay with a thickness greater than 3m.	<100
S2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A - E or S1	

References

Achenbach, J.D., 1999. Wave Propagation in Elastic Solids. North-Holland, Amsterdam, Netherlands.

Aki, K. and Richards, P.G., 1980. Quantitative Seismology, Theory andMethods, Vol. 1-2, W.H. Freeman & Co., New York.

D.M. 14/01/2008: “Technical code for Civil Engineering Projects” in italian.

Ewing, W.M., Jardetzky, W.S., and Press, F., 1957. Elastic Waves in LayeredMedia. McGraw-Hill, New York, NY.

Foti S., Lai C.G., Rix G., Roma V., 2002. Simultaneous measurement and inversion of surface wave dispersion & attenuation curves. Soil Dynamics & Earthquake Engineering Vol. 22, p. 923-930.

Hebeler G., Lai C.G., Orozco C., Rix G., Roma V., 2001. Recent advances in Surface Wave methods for Geotechnical Site Characterization. XV International Conference on Soil Mechanics and Geotechnical Engineering, Istanbul p. 27-31.

Lai and G. J. Rix, 1998. Simultaneous inversion of Rayleigh phase velocity andattenuation for near-surface site characterization", Report No. GIT-CEE/GEO-98-2. Georgia Institute of Technology, School of Civil and Environmental Engineering.

Lai C.G., 1998. Simultaneous inversion of Rayleigh phase velocity andattenuation for nearsurface site characterization", PhD Diss., Georgia Inst. ofTechn., Atlanta, Georgia, USA.

Louie J.N.: "Faster, Better: Shear-Wave Velocity to 100 Meters Depth from Refraction Microtremor Arrays", Bulletin of the Seismological Society of America; April 2001; v. 91; no. 2; p. 347-364;

Mahtab A., Stanton K.L., Roma V. "Environmental Impacts of Blasting for Stone Quarries near Bay of Fundy", 6th Bay of Fundy Workshop, September 29-October 2, 2004, Cornwallis Park, Nova Scotia.

Roma V., Lancellotta R., Rix G.: "Frequencies and wavenumbers of Resonance in horizontally stratified media for traveling Rayleigh waves ", XI International Conference on Waves and Stability in Continous Media, Porto Ercole 3-9 Giugno 2001

Roma V., Hebeler G., Rix G., Lai C.G.: " Geotechnical soil characterization using fundamental and higher Rayleigh modes propagation in layered media ", XII European Conference on Earthquake Engineering, London 9-13 Settembre 2002

Roma V.: "Automated inversion of Rayleigh geometrical dispersion relation for geotechnical soil identification ", 3rd World Conference on Structural Control, Como 7-12 April 2002

Roma V.: "Soil Properties and Site characterization through Rayleigh Waves", International Conference on Pre-failure Deformation Characteristics of Geomaterials, Lione, Settembre 2003

Roma V.: "Dynamic Soil Identification by means of Rayleigh Waves", XI Italian Seismic Engineering Conference, Genova (Italy), January 2004

Roma, V. and Mahtab, M. A. "Use of Rayleigh Waves as Reference for Determining Setback Distances for Explosions near Shorelines", Poster Session, 6th Bay of Fundy Workshop, September 29-October 2, 2004, Cornwallis Park, Nova Scotia.

Roma V., Pescatore M.: "Environmental impact caused by high speed train vibrations", International Geotechnical Conference: Soil-structure interaction:calculation methods and engineering practice, 26-28 May, 2005, St. Petersburg

Roma V., Bergamaschi M., Locatelli L., Quadrelli D. "Soil-Structure dynamic interaction: application to design and construction of the facilities of a gas power plant", XIIIth Danube-European Conference on Geotechnical Engineering (29-31 May 2006, Lubiana) Active Geotechnical Design in Infrastructure Development

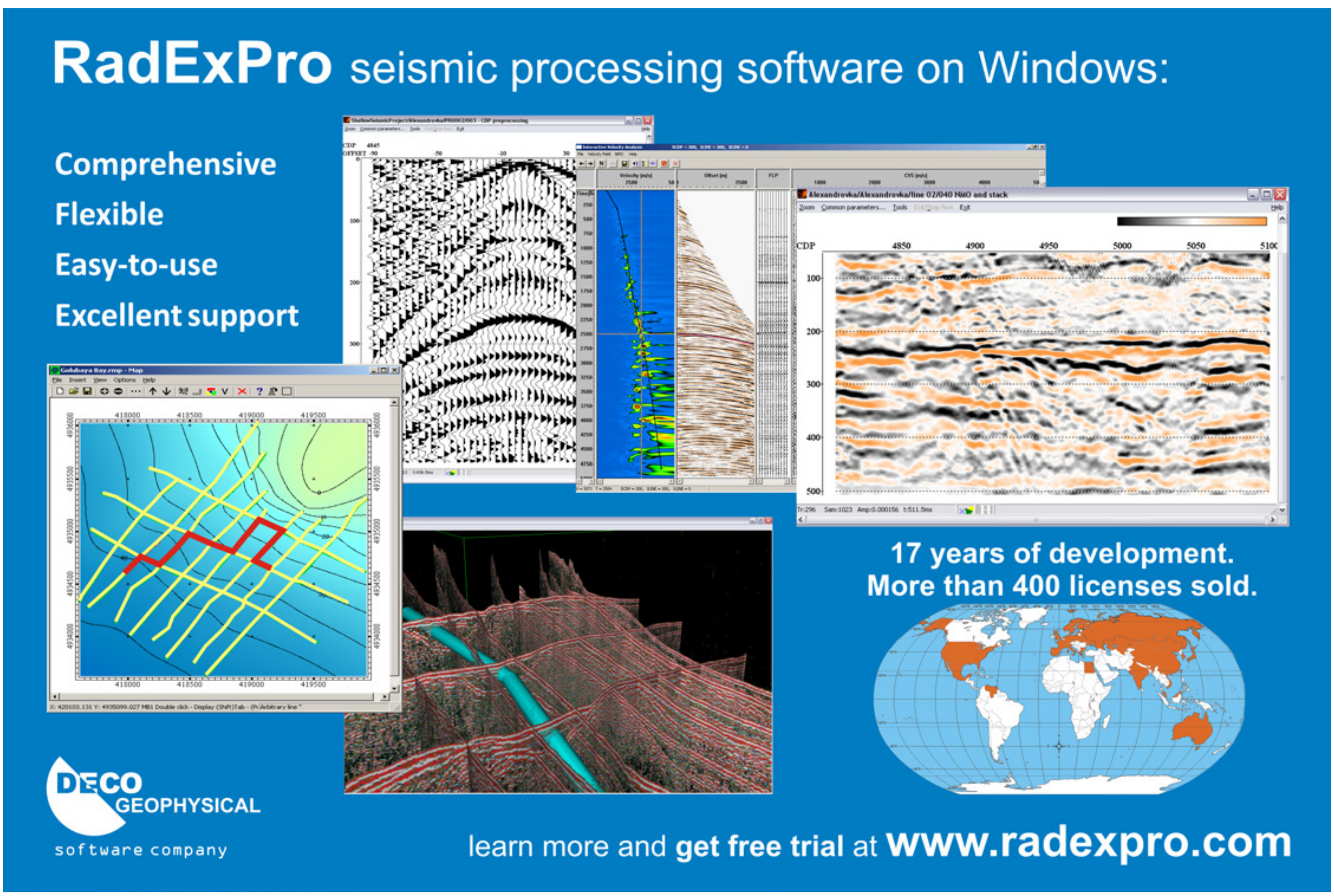
Roma V.: "Environmental impact caused by vibrations of high speed trains ", XII Italian Seismic Engineering Conference, Pisa, June 2007

Roma V.: "Seismic Geotechnical Site Characterizations by means of MASW method ", XII Italian Seismic Engineering Conference, Pisa, June 2007

Roma V. "Seismic Geotechnical Site Characterizations by means of MASW method", pdf book and handbook of the MASW software, free download from www.masw.it

Zywicki, D.J. (1999) "Advanced Signal Processing Methods Applied toEngineering Analysis

of Seismic Surface Waves." Ph.D. Dissertation,Georgia Institute of Technology.



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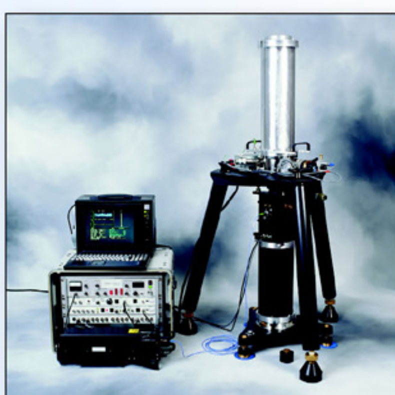

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Hockley Growth Fault Update — Mother Nature at Work!

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

In a study of the Hockley Fault in the NW part of Houston (Saribudak, 2010), geophysical results (resistivity and GPR) located the main fault plane where it crosses the Highway 290 West Frontage road and Fairfield Falls Way, and mapped a zone of distributed deformation extending about 400 feet across the fault. Since those measurements were taken, a shopping mall was built in the vicinity of the Hockley Fault zone in 2005 and 2006 (Figure 1), and Highway 290 was rebuilt and extended, covering the evidence for the fault. Since 2006, I have had the opportunity to observe continuing evidence for activity on the fault. In this note, I document observations made in April, 2010 and August, 2010 (Figure 2, A and B) that show how small cracks in pavement over the main fault trace photographed in April 2010 have extended and widened significantly by August, 2010. Note that the cracks in Figure 2B have been filled with asphalt. Saribudak, M., 2010 indicated some correlations of several small faults with the cracks observed on Highway 290 frontage roads. Figure 3 explains more on this point: Picture C shows two cracks being developed to the west of the main Hockley Fault plane. Partly stone and partly brick walls in the background indicates a unique fault defor-

Figure 1. Site map showing approximate extension of the Hockley Fault Zone defined by the geophysical and surface deformation in the vicinity of Houston Premium Outlet Shopping Mall.

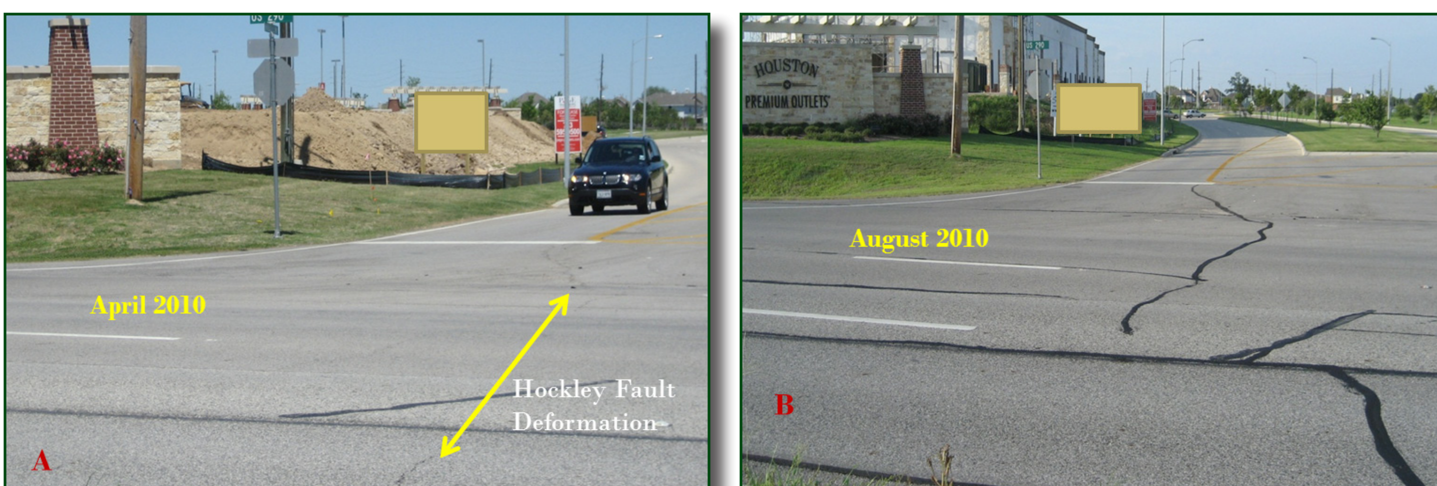

Figure 2. Recent pictures of Hockley Fault at Hwy. 290 Frontage and Fairfield Falls Way roads: A) taken in April 2010; B) taken in August 2010. Note the development of the tiny cracks in picture A into significant ones in picture B.

mation in Picture D. The brick wall appears to be separated from the stone wall due to combination of horizontal and vertical offsets expected from this type of growth fault (Saribudak, M., 2010, see page 1 and Figure 1). The original cement holding the entire brick and stone walls is no longer visible at this location due to the detachment. This type of deformation could also be due to some local slumping or erosion of fill materials beneath the brick wall.

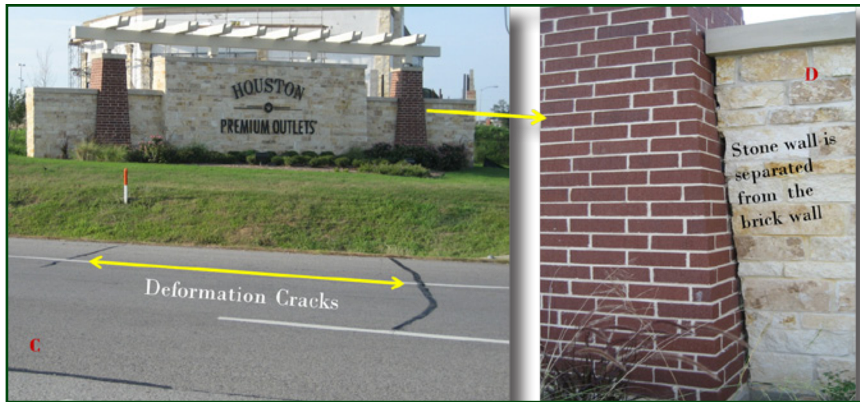

Figure 3. Pictures (C and D) of road and wall deformation to the immediate west of the Hockley Fault, respectively. The picture was taken in August 2010..

The Hockley Fault continues across the Highway 290 west and east bounds deforming the both roads (Figure 4). An alert driver can already feel the jerk given by the fault driving over Highway 290. This observation indicates the evidence that the land in Houston is changing and we are in an area where active faulting is occurring as we speak. USGS published many articles on the subject since late 1970s. Verbeek and Clanton, 1981 pointed out that there were 150 faults (now exceeding 300) in the Houston area. These faults damage road pavements, pipelines, bridges, railroad, tunnels, refineries, as well as private homes in the Houston area. In recent years, a public school in the NW part of the Houston (Tomball) was abandoned due to an active fault. Thus the fault hazard is a real threat and needs to be mitigated by avoidance and applying good engineering design and land use practices.

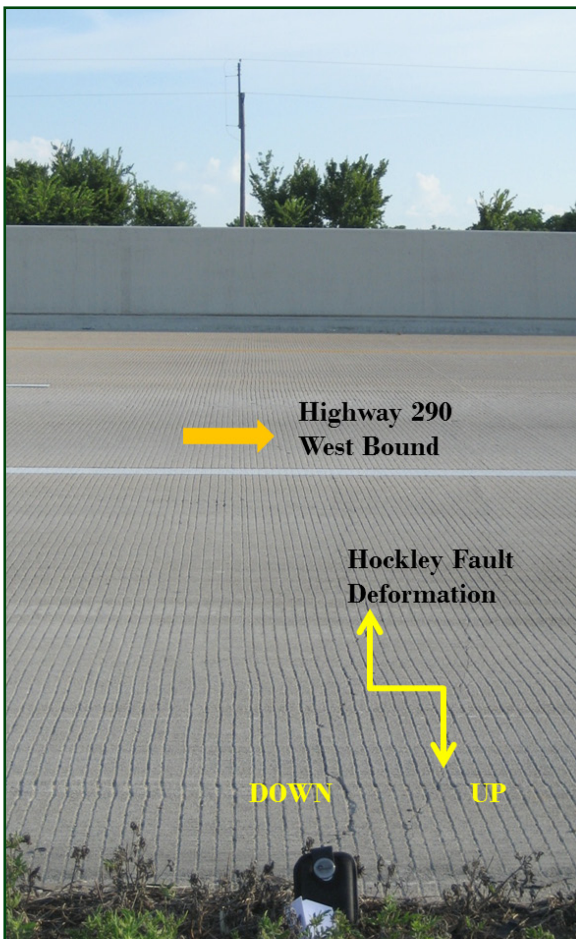

Figure 4. A recent picture (August 2010) showing revived cracks (main Hockley Fault) on the west bound of Highway 290. The fault deforms the newly built highway 290 and the feeder roads. The picture was taken facing south.

Acknowledgment

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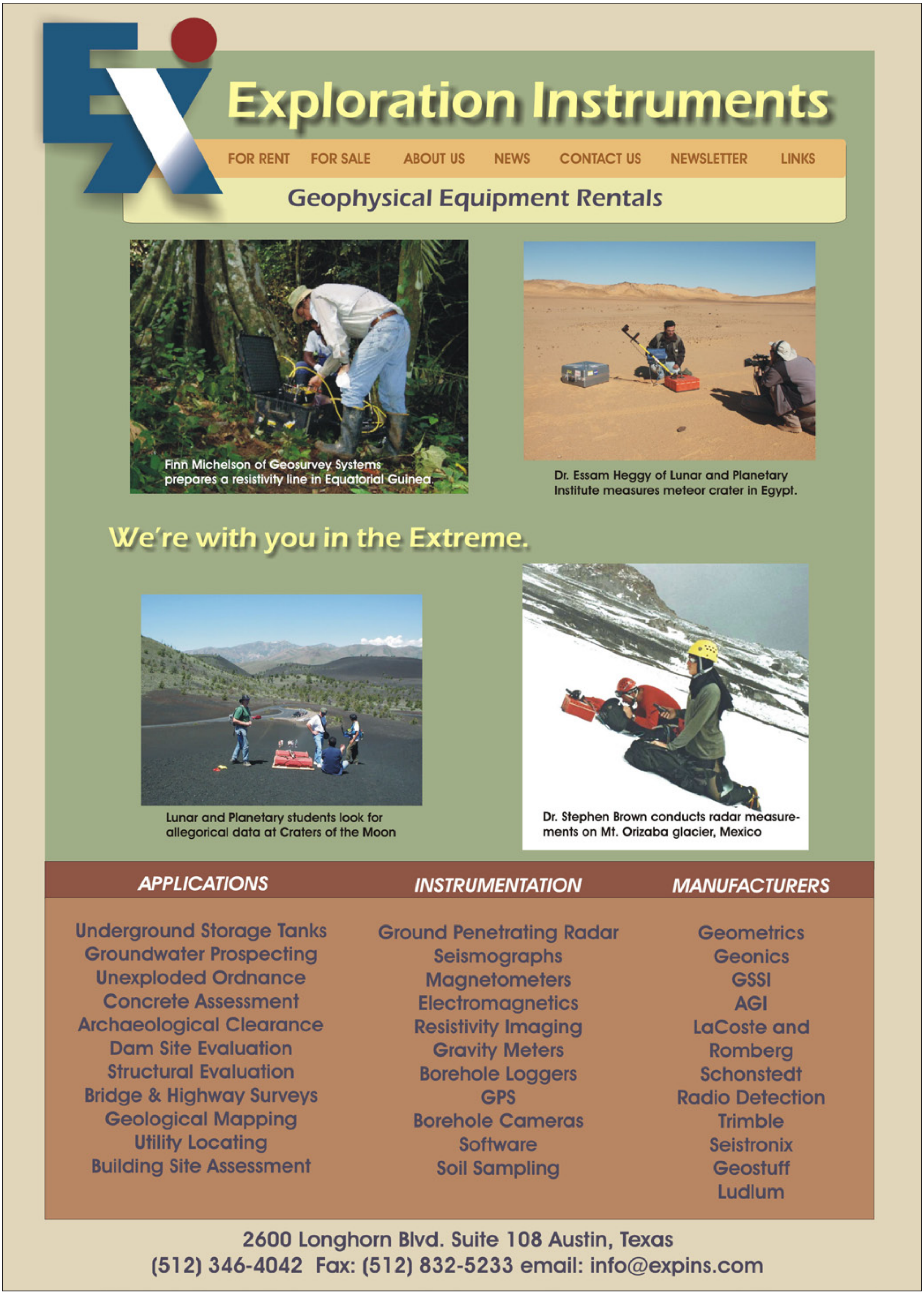
References

Saribudak, M., 2010. Geophysical mapping of Hockley Growth Fault in NW Houston, TX: A few surprising results, Houston Geological Society Bulletin, May issue. P. 43-57

Verbeek R.E., and Clanton, S.U., 1981. Historically active faults in the Houston metropolitan area, Texas, Houston area environmental geology: Surface faulting, ground subsidence, hazard liability, edited by Etter, M.E., Houston Geological Society, p. 28-69.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INSTRUMENTATION
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Shall We Use ReMiTM to Characterize Rock Slope Movements and Landslides? – Some Case Studies

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Introduction

Recently, the author's firm was retained to evaluate an apparent foundation distress problem at an electrical transmission tower high in the Chuska Mountains of northwest New Mexico. Despite exposed bedrock at the tower shallow foundations, one tower leg was clearly deformed. Prior to mobilizing a drill rig into the remote mountain site, preliminary subsurface characterization using surface seismic refraction and refraction microtremor (ReMiTM) was performed to better understand geologic conditions and assist in establishing geotechnical material parameters. In spite of presence of exposed bedrock, typical seismic refraction compression wave (p-wave) velocities near that tower leg foundation were only about 3,900 feet per second (f/s) or 1,190 meters per second (m/s) or less to depths up about 15 to 20 feet (5 to 6 meters). ReMiTM shear wave (s-wave) velocities derived from surface waves were interpreted to be only about 1,300 f/s (400 m/s). Both p-wave and s-wave velocities increased to higher values consistent with fractured bedrock below these depths. The deformed tower leg was located within a slope that appeared to have developed partly through natural processes and partly by a cut slope from the original construction. The shallow foundation was likely constructed within loose material consisting of a mass of broken rock pieces subjected to freeze-thaw action and not competent rock. After 40 years of freeze-thaw exposure and loading, slope movement in this broken rock mass occurred and deformed the tower leg. Mitigation consisted of replacing the original tower with an adjacent tower that was founded deeper into competent bedrock.

Over the last eight years, the author has collected and interpreted combined seismic refraction and ReMiTM data at a several locations where slope movement or landslide activity in a geologic material mass has been suspected. Although less precise in interpreted results than seismic refraction, ReMiTM brings several valuable attributes to surface seismic characterization. These include greater depth of investigation than refraction for a given geophone array length, and the ability to characterize

Figure 1. Photos of tower leg deformation, exposed rock at foundations, and surface seismic refraction and ReMiTM field evaluation.

below velocity reversals and under the water table where refraction is severely limited. Some observations of surface seismic results may be instructive, or at least be part of a conversation, of using surface seismic for characterizing potential or active slope movement conditions or landslide features.

Methodology

The refraction microtremor (ReMiTM) method (Optim, 2004) uses surface waves (Rayleigh waves) to characterize the subsurface as 1-dimensional vertical shear wave (s-wave) depth profiles. Lateral variations can be characterized with overlapping or adjacent profiles. Introduced by Louie (2001), it became available commercially in 2002. Originally optimized for earthquake seismic site characterization, ReMiTM is an effective geophysical tool for geotechnical engineering, especially when the non-unique interpretations are constrained by other subsurface information. The author has, since 2002, used a combination of seismic refraction and ReMiTM as a standard characterization tool in geotechnical investigations. Both methods are performed using the same geophone arrays, usually 4.5 Hz geophones at 10-foot (3-meter) spacing and a 12- or 24-channel seismograph. Seismograph settings are changed to collect the higher frequency seismic refraction data and low frequency ReMiTM data. As described in Rucker (2006), strengths and weaknesses of each surface seismic method are complementary. Combining interpretations of both seismic refraction and ReMiTM at the same location can result in more complete and robust characterization than with either method alone.

Some Background – P-wave Seismic Velocities at Rock Slope Failures

One Sunday afternoon in 1996, a manager with the author's firm was driving home on a rural highway in central Arizona from a weekend at his cabin. Shortly after he passed by a large rock cut in progress through a highway-widening construction zone, he heard a loud roar. Looking in his rear-view mirror, he saw a billowing wall of dust that obscured the cut zone behind him. A portion of the slope had failed and collapsed onto the new roadway excavation below. Jersey barriers at the construction site edge blocked the debris from the existing roadway.

The new cut height was in excess of 100 feet (30 meters) in a rock mass consisting of slightly to highly weathered Pre-Cambrian schist interbedded with phyllite having predominantly high angle foliations and fractures. Based on a nearby design boring completed in 1993, below the highly weathered upper 20 or more feet (6 meters), Rock Quality Designation (RQD) averaged 66 percent, but ranged from 0 to 100. Large zones of slightly to moderately weathered, high RQD recovered core, and smaller zones of highly weathered to decomposed low RQD recovered core were logged. No borings were completed at the ultimate slide location during the design investigation; the mountain slope was too steep and rugged to pioneer access for a drill rig (small rigs mobilized by helicopter became available a few years later, and have solved that problem). No seismic refraction work was performed as part of the 1993 design work.

During the bidding process in 1995, one contractor engaged the author to perform several seismic lines across the project to provide information for estimates on general rippability (CAT 1984, 1993) and excavation conditions. One-half of a 300-foot (91 meter) seismic refraction line, completed with a 12-geophone array and sledgehammer energy source, was performed over the future failure zone. A compression wave (p-wave) velocity of 4,800 feet/second (f/s) (1,460 meters/second) at the future failure location was estimated to a depth as great as about 52 feet (16 meters) based on intercept time method (ITM) interpretations in the forward and reverse directions. Other interpreted p-wave velocities below the surface soil / decomposed rock horizon in adjacent seismic line sections ranged from about 6,500 to 9,500 f/s (1,980 to 2,900 m/s).

The eventual rock slope failure zone correlated with a pre-construction in-situ p-wave velocity of only about 4,800 f/s. This was the lowest relatively deep p-wave velocity zone measured during the seismic evaluation. Due to the extreme time-sensitive nature of the seismic results in the bidding process, the seismic work was submitted as draft, and was never finalized.

Another case of rock slope failure during construction of additional lanes for another central Arizona rural highway occurred in 2000. A deep cut in weathered, fractured Pre-Cambrian granites included a slightly over-steepened rock slope at the base of a major electrical transmission line tower. Seismic refraction work included in the investigation for design was performed in 1997 (Rucker, 2000). Interpreted p-wave velocities in the vicinity of the over-steepened slope were 5,000 f/s (1,520 m/s) or less to depths of about 23 to 50 feet (7 to 15 meters). During construction, excavation in the deeper, more competent rock at the cut section included blasting. One day, while servicing the blast monitoring seismograph at the tower, a construction engineer noticed a new ground crack propagating between the four tower legs. As the crack width increased, it became apparent that the rock mass in the over-steepened slope was sliding down into the excavation. A leaking construction water pipeline at the slope crest may also have contributed to weakening the slope. The slope was rapidly re-engineered and modified, and an emergency tower was placed at a safe distance from the crest. Again, failure of a weathered, fractured rock mass correlated with a pre-construction in-situ p-wave velocity of about 5,000 f/s (1,520 m/s) or less.

Figure 2. Views of rock cut area in weathered, fractured granites before and after excavation. The tower on the right is the replacement tower after the slope was re-engineered and reconstructed.

More Background - Relevant Rock Parameters

A common theme in the above examples is that seismic velocity is a measure, or at least an indicator, of rock mass strength. Primary parameters of rock mass strength include intact rock particle strengths, discontinuity (jointing and fracturing) intensity and orientation, and the absence or presence of groundwater. Slope failure occurs when steepening slopes or increased loads exceeds the capability of the rock mass strength to resist failure. Unconfined or uniaxial compression strength (UCS) is a common measure of intact rock particle strength, and RQD is a common measure of discontinuity intensity.

How do UCS and RQD compare and relate to seismic velocity? Studies comparing UCS with p-wave velocity are summarized by Barton (2007), and reasonable relations between UCS and seismic velocity have been developed (i.e., Rucker, 2008) based on material modulus and limited data sets. Using the Rucker (2008) method and assuming intact rock (RQD = 100), at seismic velocities of 10,000 f/s and 5,000 f/s (3,050 m/s and 1,520 m/s), UCS values of about 2,000 psi and 200 psi (13.8 MPa and 1.4 MPa), respectively, can be anticipated. However, discontinuities in a rock mass significantly reduce seismic velocity (and rock mass strength). Deere and others (1967) related RQD to intact (laboratory) and field seismic velocity through a concept of velocity ratio:

$$RQD = 100 \times \frac{V_{field}^2}{V_{intact}^2}$$

where Vs are the field and intact seismic p-wave velocities and RQD is calculated into percentage. Using this estimation procedure, a rock mass with a typical intact particle UCS of 2,000 psi but a seismic field p-wave velocity of only 5,000 f/s, may have an RQD of only about 25.

Figure 3. Examples of granite rock cores. The shallower, low RQD core on the left is from a zone with a seismic p-wave velocity of about 5,000 f/s (1,520 m/s). The deeper, higher RQD core on the right is from a zone with a seismic p-wave velocity of about 9,000 f/s (2,740 m/s).

It should be noted that intact, unfractured and unjointed rock masses, such as some welded tuffs and intact sedimentary rocks, with relatively low UCS but moderate field seismic velocity, may be able to stand as a steep or vertical slope. However, a fractured, jointed rock mass with equivalent field seismic velocity could slide and fail along critically oriented fracture or joint planes. Groundwater seepage can increase rock mass weight supported at critically oriented fracture or joint planes, while seepage along those critical planes could reduce sliding friction resistance and trigger movement or failure.

Case Study with ReMiTM as Critical Surface Seismic Method

An investigation for upgrading a small forest highway bridge in northern California included surface seismic refraction and ReMiTM as well as surficial geologic mapping and borings for geotechnical characterization. The site is in a Tertiary to Jurassic bedrock terrain within the Central Belt of the Coast Ranges Province Franciscan Complex (McLaughlin and others, 2000) containing highly deformed and metamorphosed rock. Landslide deposits, including both shallow colluviums over bedrock and detached bedrock, are common in portions of the sloping terrain. The intent of the surface seismic work was to evaluate the subsurface along existing cut faces for adjusting approach roadways for replacement bridge design. Planned depth of investigation for the surface seismic work was 30 feet (9 meters).

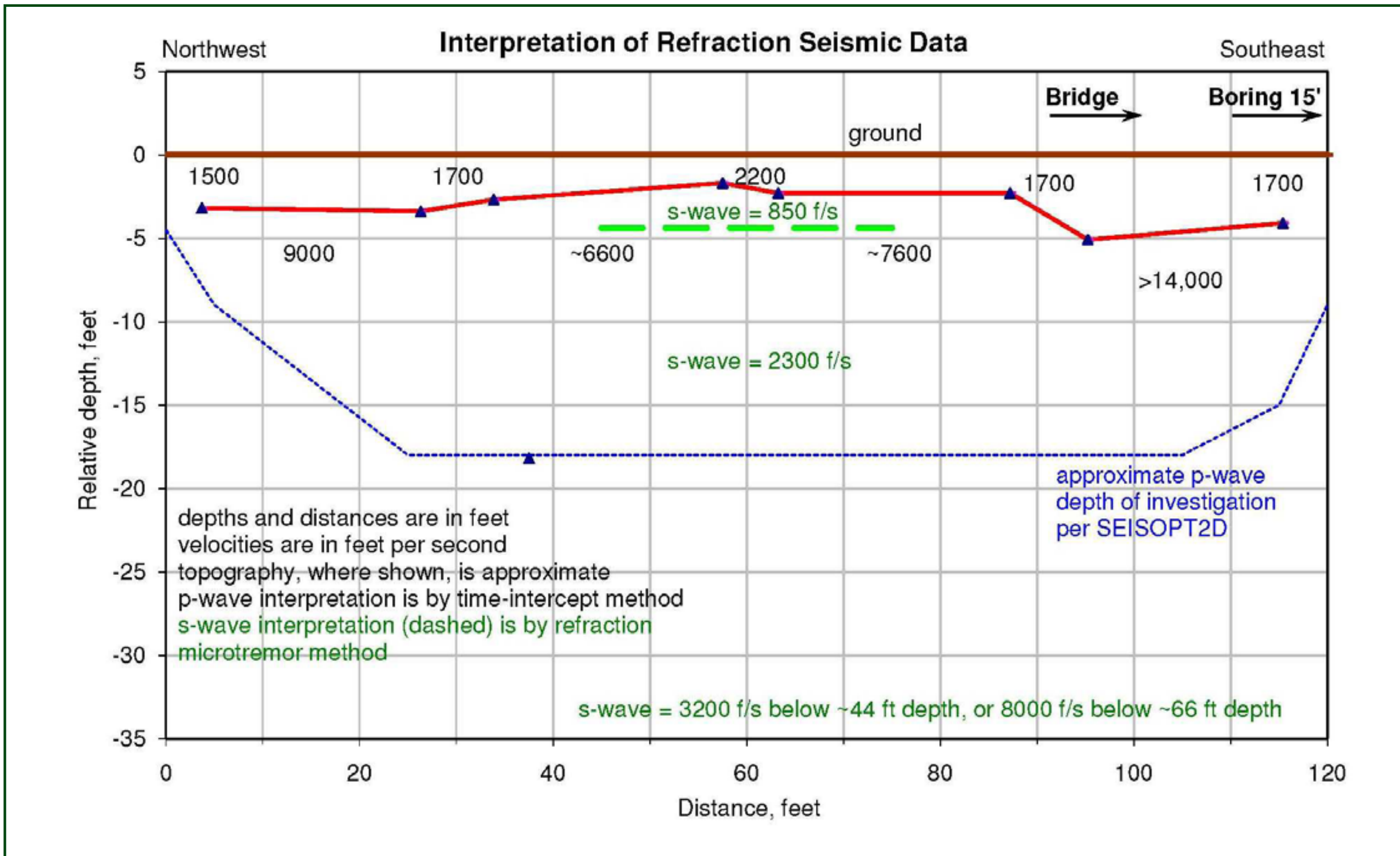

Figure 4. Results of ITM p-wave interpretation, including p-wave depth of investigation and 1-dimensional ReMi^{TM} S-wave profile interpretation. All seismic velocities are in feet per second.

Interpretation results at one seismic line completed along the toe of a small road cut face were unusual, and demonstrate the value of using complementary surface seismic methods as standard practice. As shown in Figure 4, several feet of soil with p-wave velocities of 1,500 to 2,200 f/s (460 to 670 m/s) was interpreted to overlie competent rock with p-wave velocities ranging from 6,600 to 7,600 f/s (2,010 to 2,320 m/s) in the center 60 feet (18 meters) of the line to as high as 9,000 to 14,000 f/s (2,740 to 4,270 m/s) in 30-foot (9-meter) sections at either end of the seismic line. P-wave velocities in the seismic line center were consistent with fractured, jointed rock, while p-wave velocities at the seismic line ends were consistent with intact bedrock. A shallow groundwater table saturating rock mass joints and fractures could cause higher p-wave velocities and lead to misinterpretation of the rock mass condition and strength. However, the stream channel elevation was about 20 feet (6 meters) lower than the seismic line within a distance less than 100 feet (30 meters), and a nearby boring reported an estimated depth to water of 21 feet (6.4 meters). The interpreted p-wave depth of investigation was only about 18 feet (5.5 meters). Based on the p-wave results alone, a reasonable interpretation was that shallow bedrock was present within depths of about 3 to 5 feet (0.9 to 1.5 meters). A significantly fractured or jointed zone in the bedrock was present at the seismic line center, and more competent bedrock was present at the seismic line ends. If needed, efficient bedrock excavation would likely require hard ripping in some areas and blasting in some areas (Cat, 1984, 1993).

The ReMi^{TM} interpretation at the same seismic line setup (only the seismograph settings were changed) presents a completely different interpretation of the subsurface. As shown in Figure 5, a 4-foot (1.2 meter) soil horizon with s-wave velocity of about 850 f/s (260 m/s) is underlain by a deep horizon with an s-wave velocity of about 2,300 f/s (700 m/s). Interpreting only the most coherent higher frequency (>14 Hz) portion of the dispersion data, this horizon extends to a depth of about 44 feet (13 meters). The deepest interpreted s-wave velocity may be about 3,200 f/s (980 m/s); that would not represent a true competent bedrock velocity. Interpreting all of the dispersion data, including perhaps less-coherent dispersion data down to 6 Hz, results in a depth of about 66 feet (20 meters) to a contact with bedrock-type s-wave velocity of about 8,000 f/s (2,440 m/s). Neither interpretation is consistent with shallow competent bedrock as suggested by the p-wave data.

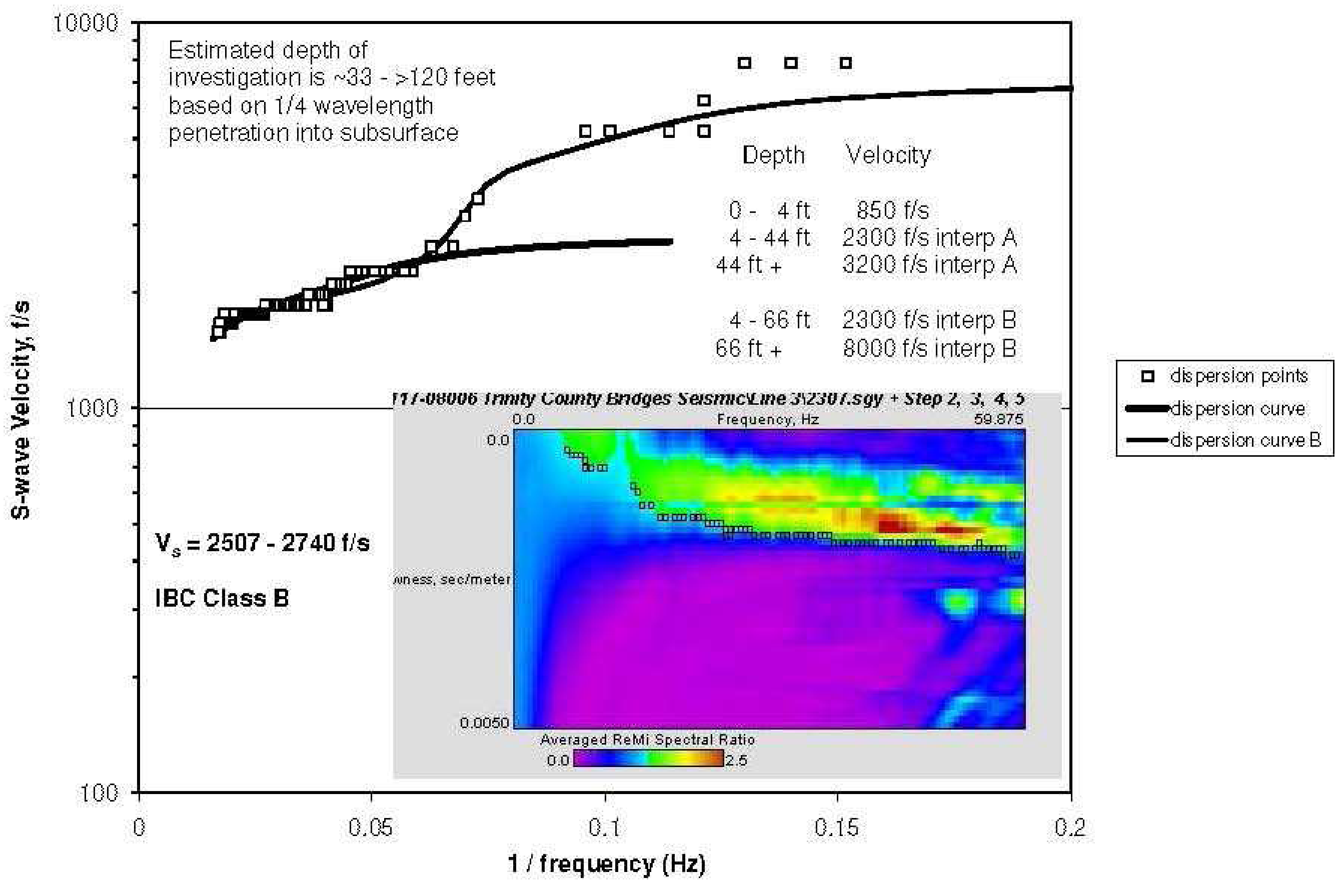

Figure 5. ReMi™ interpretation at seismic line in Figure 4. Two alternative interpretations, one based on the shallow data points only using surface waves with frequency higher than 14 Hz, and one based on all of the data points with frequency down to 6 Hz, were performed. To incorporate the shallow portion of the subsurface, the maximum dispersion frequency was set at 60 Hz.

A few weeks after the seismic work was completed, an exploratory corehole advanced to a depth of 66.7 feet (20.3 meters) was completed at 15 feet (4.6 meters) beyond one end of the seismic line just beyond the end of the existing small road cut. Fill was logged to a depth of about 6.5 feet (2 meters), and depth to groundwater was estimated to be 21 feet (6.4 meters). Below the fill, landslide debris consisting of alluvial terrace deposits and then displaced rock composed of meta-graywacke and meta-argillite was logged. Multiple zones of crushed and sheared rock were logged; the deepest such zone, logged as a possible shear zone or landslide slip surface, was at a depth of about 61.5 feet (18.8 meters). RQD was non-applicable to a depth of about 52 feet (15.9 meters). Below that depth to the bottom of the corehole, RQD ranged from 24 to 40 in interbedded meta-argillite and metagraywacke. Below a depth of 61.7 feet (18.8 meters), Metagraywacke of Hammer Horn Ridge was logged.

Cross-comparison of the boring with the seismic results was instructive. The zone of broken rock with no RQD to a depth of 52 feet compared very favorably with the ReMi™ s-wave velocity of about 2,300 f/s to a depth of about 44 feet in one interpretation. Similarly, the zone of low rock RQD beginning at a depth of 52 feet compared favorably with the ReMi™ S-wave velocity interpretation of about 3,200 f/s in that interpretation. The alternate interpretation placed bedrock at a depth of about 66 feet, which was slightly deeper than the deepest shear zone or landslide slip surface logged at a depth of 61.5 feet. The ReMi™ results appeared to reasonably characterize detached bedrock shear zone or landslide conditions in the subsurface to depths at or greater than the length of the geophone array.

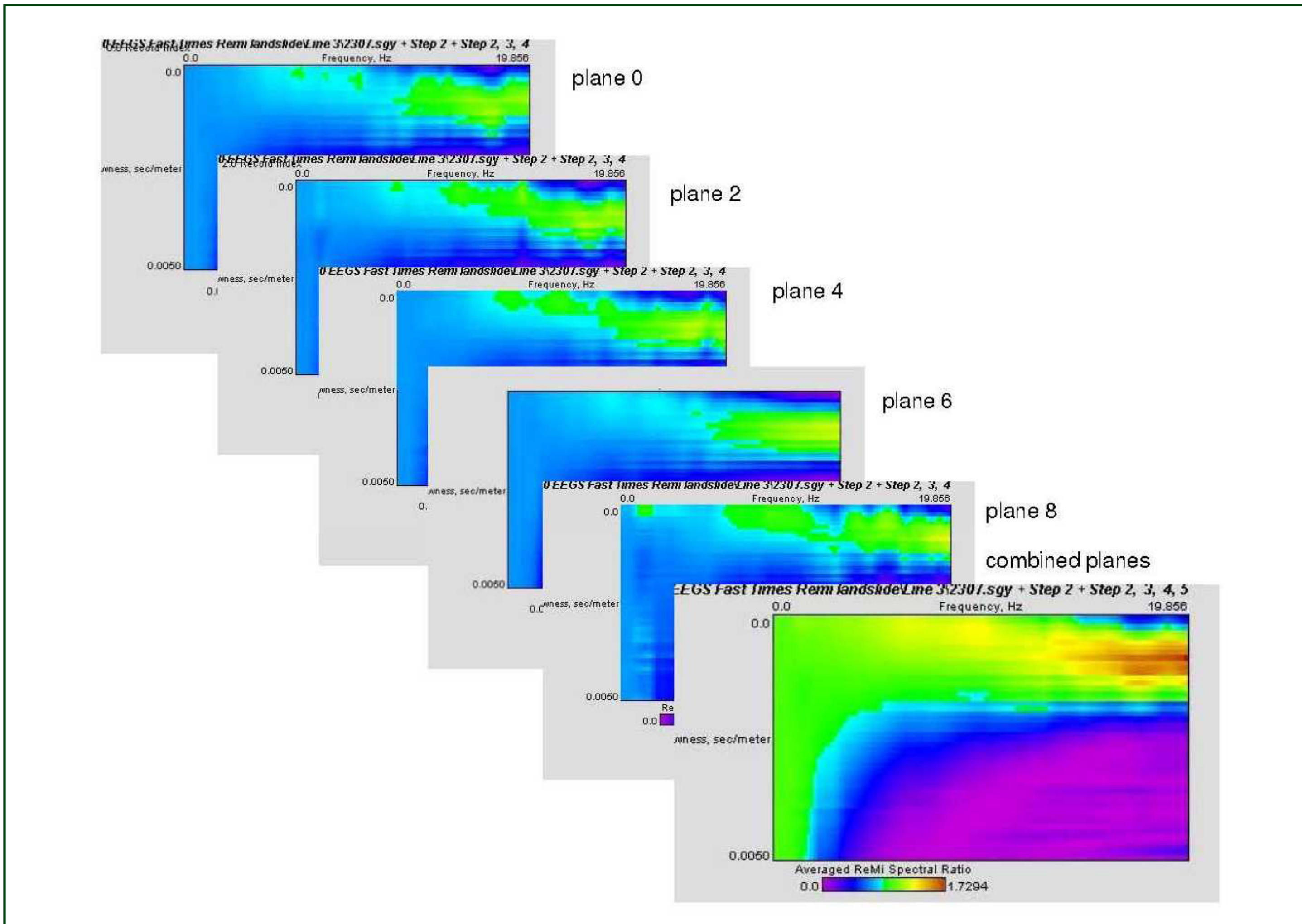

Figure 6. Dispersion recomputed at a maximum frequency of 20 Hz. Individual spectral planes and the resulting combined planes are shown. Program settings were not modified from the standard settings.

What of the P-wave interpretation of shallow bedrock? Each of the two zones of high P-wave velocity consistent with intact bedrock were only about 30 feet (9 meters) in length. In a situation of a detached bedrock-type of landslide movement, very large particles of intact rock could be floating in the landslide debris mass. If encountered during construction, such very large particles could still present local excavation difficulties equivalent to bedrock. Understood within it's constraints, the P-wave interpretation was correct, but needed to be placed into a correct geologic setting. The ReMi™ interpretation could not provide the two-dimensional detail in the shallow subsurface needed for geotechnical characterization that was obtained from seismic refraction (Figure 4). The S-wave velocity interpretation (Figure 5) would significantly underestimate the excavation difficulty deeper than a few feet below the existing ground surface, and could mislead contractors bidding on the future construction work.

The low frequency component of the ReMi™ dispersion data in Figure 5 was less certain than the high frequency component. For this paper, the author re-evaluated the low frequency portion of the dispersion data. From examination of the dispersion spectrum in Figure 5, it was observed that the larger range of spectral ratio was between about 25 Hz to 55 Hz Recomputed at a maximum frequency of 20 Hz, the high frequency, shallow portion of the dispersion was removed, as shown in Figure 6, to see if low frequency resolution could be improved.

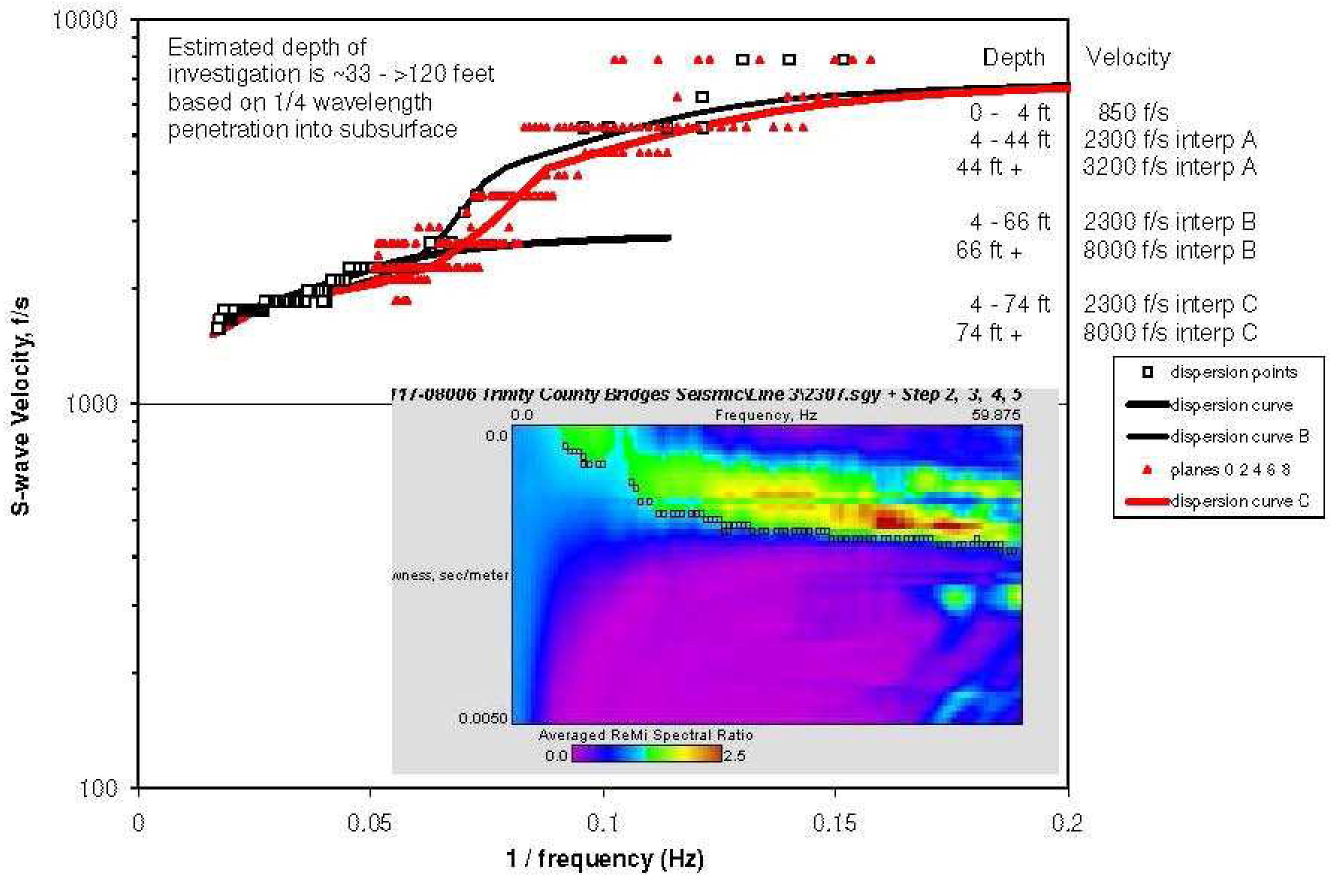

Figure 7. Revised interpretation with enhanced evaluation of the low frequency portion of the dispersion curve. The overall result is a somewhat deeper interpretation of depth to bedrock. Data was collected with the intent of shallow subsurface evaluation using only 12 channels; 24 or more channels may improve results at greater depth.

As demonstrated in Figure 6, program settings would need to be modified to follow the normal dispersion data picking process at the boundary of green and blue in the spectral ratio plot. Several solutions to the problem are possible. The ReMi™ program settings could be modified to adjust the spectral ratio presentation. Dispersion data could be picked from a different color boundary, perhaps green and yellow in the case of Figure 6. Finally, dispersion data could be picked for each individual plane (such as in Figure 6) and manually combine the results. An example of the last approach is presented in Figure

7. Dispersion picks are shown as red points, and a new interpretation based on those picks is shown as a red line. The result is a somewhat deeper depth to bedrock interpretation. The general result of the Figure 6 interpretation, a probable detached bedrock landslide feature, is unchanged.

Conclusions

Surface seismic methods are an effective but underutilized tool for evaluating potential rock slope failures and landslides. ReMi^{TM} is an effective tool for site characterization in areas of potential landslides and other geologic material mass movement. Its' advantages include relatively deep investigation depth compared to geophone array length, and use of ambient surface wave noise that permits data collection in noisy (such as urban or highway) environments. The non-unique nature of ReMi^{TM} results and interpretations must be respected and, whenever possible, constrained by other data such as seismic refraction or exploratory drilling.

References

Barton, N., 2007, Rock Quality, Seismic Velocity, Attenuation and Anisotropy, Taylor & Francis/ Balkema, London, UK, pp. 25-27.

Caterpillar Tractor Company, (Cat), 1984, Caterpillar Performance Handbook, Edition 15, Peoria, Illinois, October.

Caterpillar Tractor Company, (Cat), 1993, Caterpillar Performance Handbook, Edition 24, Peoria, Illinois, October.

Deere, D.U., Hendron, A.J., Patton, F.D. and Cording, E.J., 1967, Design of surface and near surface construction, In: Rock, Failure and Breakage of Rock, Fairhurst, C. (ed.): 237-302. New York, Society of Mining Engineers of AIME.

Louie, J.L., 2001, Faster, better: Shear-wave velocity to 100 meters depth from refraction microtremor arrays: Bulletin of the Seismological Society of America, 91, 347-364.

McLaughlin, R.C., Ellen, S.D., Blake, M.C. Jr., Jayko, A.S., Irwin, W.P., Aalto, K.R., Carver, G.A., Clarke, S.H. Jr., Barnes, J.B., Cecil, J.D. and K.A. Cyr, 2000, Geology of the Cape Mendocino, Eureka, Garbervill and Southwestern Part of the Hayfork 30x60 Minute Quadrangles and Adjacent Offshore Area, Northern California.

Optim, 2004, SeisOpt@ReMiTM Version 3.0, Optim LLC, UNR-MS 174, 1664 N. Virginia St, Reno NV, 89557-0141 USA

Rucker, M.L., 2000, Earthwork factors in weathered granites by geophysics, in Nazarian, S. and Diehl, J. (eds), Use of Geophysical Methods in Construction, Geotechnical Special Publication No. 108: ASCE, Reston, Virginia, 201-204.

Rucker, M.L. 2006, Integrating Seismic Refraction and Surface Wave Data Collection and Interpretation for Geotechnical Site Characterization, 2006, FHWAGeophysics2006, St. Louis, Mo., December 4-7. http://www.optimsoftware.com/white_papers/images/FHWA2006RuckerP-waveS-wave.pdf

Rucker, M.L., 2008, Estimating in-situ geo-material mass density, modulus and unconfined compressive strength from field seismic velocity measurements, Highway Geophysics-Nondestructive Evaluation Conference, Charlotte, NC, Dec. 1-4.

Multi-Frequency EM Surveys Help Identify Possible Near-Surface Migration Pathways in Areas Surrounding a CO_2 Injection Well: San Juan Basin, New Mexico, USA

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Introduction

Approximately 70 line-kilometers of multi-frequency EM data were collected over a carbon sequestration pilot site in the north-central part of the San Juan basin. The study was conducted as part of for the Southwest Regional Partnership (SWP) on Carbon Sequestration's San Juan Basin Fruitland Coal pilot test. The project was funded by the U.S. Department of Energy and was managed by the National Energy Technology Laboratory (NETL). The efforts reported on here were undertaken as part of the NETL Phase II Regional Partnership activities. The pilot test was undertaken in collaboration with ConocoPhillips as a joint enhanced coalbed methane recovery test and demonstration of CO_2 sequestration in deep, unmineable coal seams. The SWP conducted the pilot in the Upper Cretaceous High Rate Fruitland production fairway southwest of the northwest trending basin hinge. CO_2 injection began July 30th of 2008 and continued through August 14th of 2009. During the 12 month injection period approximately 319 MMCF, equivalent to nearly 18,407 short tons of CO_2 were injected into the Fruitland coals. The EM data were collected to locate flow paths in the near-surface sandstone that caps the site mesa that would vent CO_2 if it were to escape from the Fruitland coal injection zone. The Fruitland coals are located between 3000 and 3200 feet beneath the surface in the area.

An earlier model Aeroquest Sensortech (formerly Geophex) GEM-2 terrain conductivity meter was used to acquire the data. Data were collected at 4 frequencies: 45,030Hz, 16,890Hz, 4,110 Hz and 1,050 Hz At the time, the GEM-2 instrument did not have built-in stepping mode frequency transmission. In this study, data were initially collected using simultaneous transmission of all 4 frequencies. Data were re-acquired in select areas using only two simultaneous transmission frequencies: one high and one low. The survey was run twice to obtain observations at all four frequencies. In this case, transmission power at individual frequencies was higher and the recorded data had higher signal-to-noise ratio. Inverse models developed from both data sets using Interpex Limited IX1D v3 software contain noticeable differences. Inverse models developed from data recorded using only two transmission frequencies provided more continuous (less noisy) views of subsurface conductivity layering.

Background Geology of the Site

Approximately 70 line kilometers of EM data were collected over the pilot site to locate flow paths in the near-surface sandstone that caps the site mesa. The major purpose for acquiring the EM data was to locate high porosity, high-permeability near-surface zones that might vent upward migrating CO_2 and facilitate atmospheric return.

CO_2 was injected into the upper Cretaceous Fruitland coals at the site. There are three major coal seams in the injection zone. The upper and middle coals are both approximately 20 feet thick (6.1 meters) and the lower coal is close to 30 feet thick (9.1 meters). The CO_2 injection well is located on a mesa in the north central part of the San Juan Basin (Figure 1). The ground elevation at the injection well is 6321 feet (1927 meters) above sea level. Bedrock geology in the area consists primarily of nearly flat lying

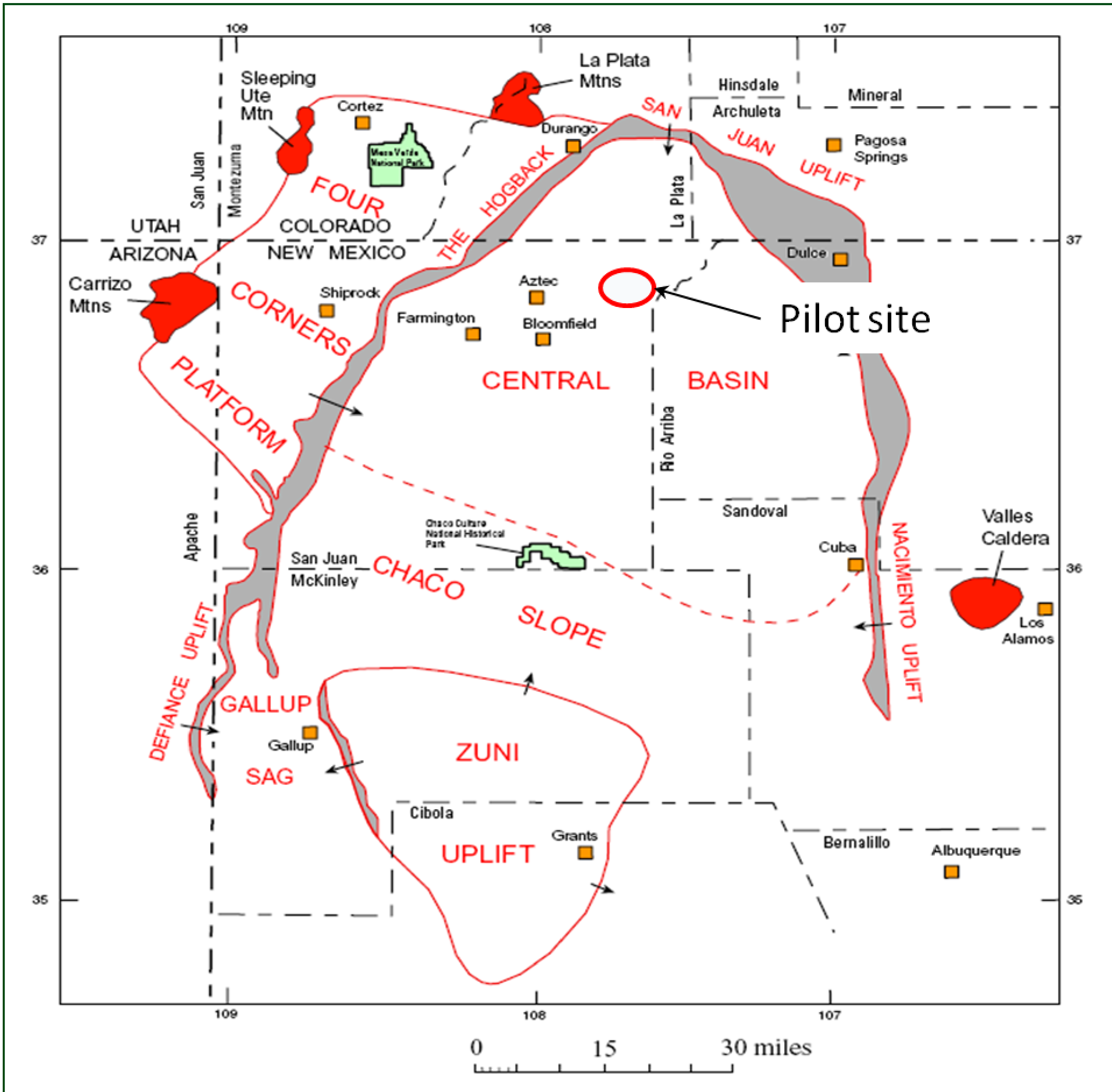

Figure 1. The location of the pilot site is shown in general with reference to the outline of the San Juan Basin located in the northwestern corner of New Mexico. The northern most edge of the basin extends into the southwest corner of Colorado (Taken from Fassett, 2000).

tan conglomeritic sandstone and shale of the Cuba Mesa Member of the basal Eocene age San Jose Formation (approximately 54 My age). The mesa is covered in places by colluvium of varying thickness. Exposures along the mesa rim are dominated by a series of sandstone and shale layers. The mesa is underlain by a thick (~11 meter (36 foot)) sandstone (Figure 2). A thin shale (1.2 meters (4feet) thick) lies at the base of the sandstone (Figure 3). This pattern of alternating sandstone and shale intervals is prevalent throughout the area (Figure 4). Evidence of active drainage during wetter periods as well as seep and spring activity are notable along the flanks of the mesas in the region.

A photo from beneath the edge of the mesa near the canyon head (Figure 4) provides perspective on the scale of the intervals being investigated using the GEM-2. The massive sandstone is approximately 11 meters thick; it is underlain by a weaker shale interval that measures approximately 1 – 2 meters thick in the area. The canyons in the regoin appear to develop primarily through groundwater sapping. The process is common throughout the area and was initially observed along the perimeter of the mesa to the southwest. Massive sandstone layers form the resistant mesa floor and the prominent benches along the canyon wall (Figures 3 and 4) are underlain by seeps in places. The underlying shales are preferentially eroded. Rock falls often point up-slope to seeps beneath the lip of massive sands that cap the mesa and form benches along mesa flanks. Headword erosion occurs in this fashion, widening and extending headward canyon development.

The view down the length of one of these canyons (Figure 4) reveals about 60 meters (200 feet) of the section underlying the site mesa. The EM survey was undertaken to provide information about conductivity variations within the upper 10 to 12 meters (33 to 40 feet) of section capping the mesa.

EM Survey Method

The Aeroquest Sensortech (formerly Geophex) GEM-2 multi-frequency terrain conductivity meter was used to evaluate the EM response of the site at several transmission frequencies. Recordings were made at 45,030Hz, 16,890Hz, 4,110 Hz and 1,050 Hz The high frequency (45,030 Hz) response (Figure 5) reveals a complex pattern of conductivity variation through the area. Data in some areas of the survey were collected at different times. To evaluate chang-

Figure 2. The CO_2 injection well is located in middle-left of the photo. The massive sandstone underlying the site is exposed in a canyon-head south of the injection well.

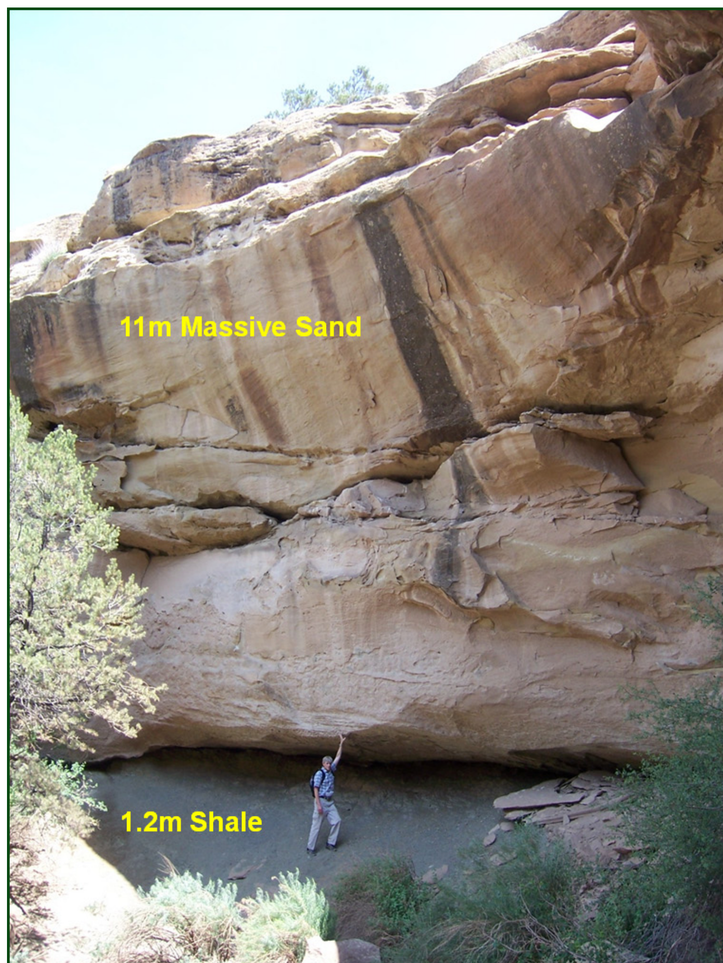

Figure 3. Massive sand that caps the site mesa. A weathered shale zone is observed at the base. Preferential erosion of the shale undercuts the sandstone layer.

es that might be associated with differences in recent precipitation and water saturation of near-surface intervals, surveys incorporated overlap and in some cases were repeated to determine if significant differences in EM response occurred through time. Anomaly amplitudes were observed to vary with time; however, similar, nearly identical patterns were observed in the terrain conductivity response.

EM surveys were carried out along east-west lines spaced at 10 meter intervals across the site. Line-of-site navigation along individual lines was not possible in the area. Real-time GPS positioning was used to track measurement locations. A hand held GPS unit along with guidance from a field assistant in foresight or backsight locations was used to maintain profile location during individual line surveys.

In its original configuration, the GEM-2 was set up to transmit all selected frequencies simultaneously. In this configuration the transmitter power is divided between selected frequencies and reduces transmitted power at individual frequencies. To increase transmission power, the surveys were repeated in selected areas. In the repeat surveys, transmission was limited to two frequencies (one high and one low) to enhance transmitted signal strength and improve depth of penetration. This required that the area had to be surveyed twice to obtain coverage at the four frequencies acquired in the earlier surveys. In the following discussions we present comparisons to illustrate differences in EM response. Differences are particularly noticeable at lower frequency. We also present inverse models along a profile line developed using Interpex Limited IX1D v3 software. The inverse models provide insights into the conductivity variations as a function of depth and spatial location at the site. They also illustrate the improvement in data quality obtained by limiting transmission to a couple frequencies.

Figure 4. View out along the mesa edge reveals an alternating sequence of sandstones and shale layers underlying the CO_2 well site.

Results

Comparison of the lowest frequency (1,015 Hz) quadrature components (Figure 6) reveals that both data sets are chaotic in appearance. The data collected using only two transmitted frequencies (Figure 6B) has smaller range (approximately 0 to 400 ppm of the primary field). Whereas the data collected using four simultaneously recorded frequencies (Figure 6A) has much greater variability (300 to -3000 ppm) with values mostly in the negative.

Coherent patterns begin to appear in the 4,110Hz data over the area (Figure 7). The low conductivity area noted in the regional 45,030Hz view (Figure 5) is not revealed in the 4,110Hz data acquired initially (Figure 7A). The earlier (2007) data reveal a very noisy low frequency response which contributed large errors to the EM inversions. The recent (2008) survey provides more coherent views (Figure 7B) of induced EM fields at the 4kHz frequency and suggests that lower error inversions will be possible.

The 16,890 Hz data continues to reveal improvements in signal-to-noise ratio when the number of simultaneously recorded frequencies is reduced (Figure 8). Features in the 16,890 Hz data set, recorded with only one additional frequency (Figure 8B), are more coherent and well defined.

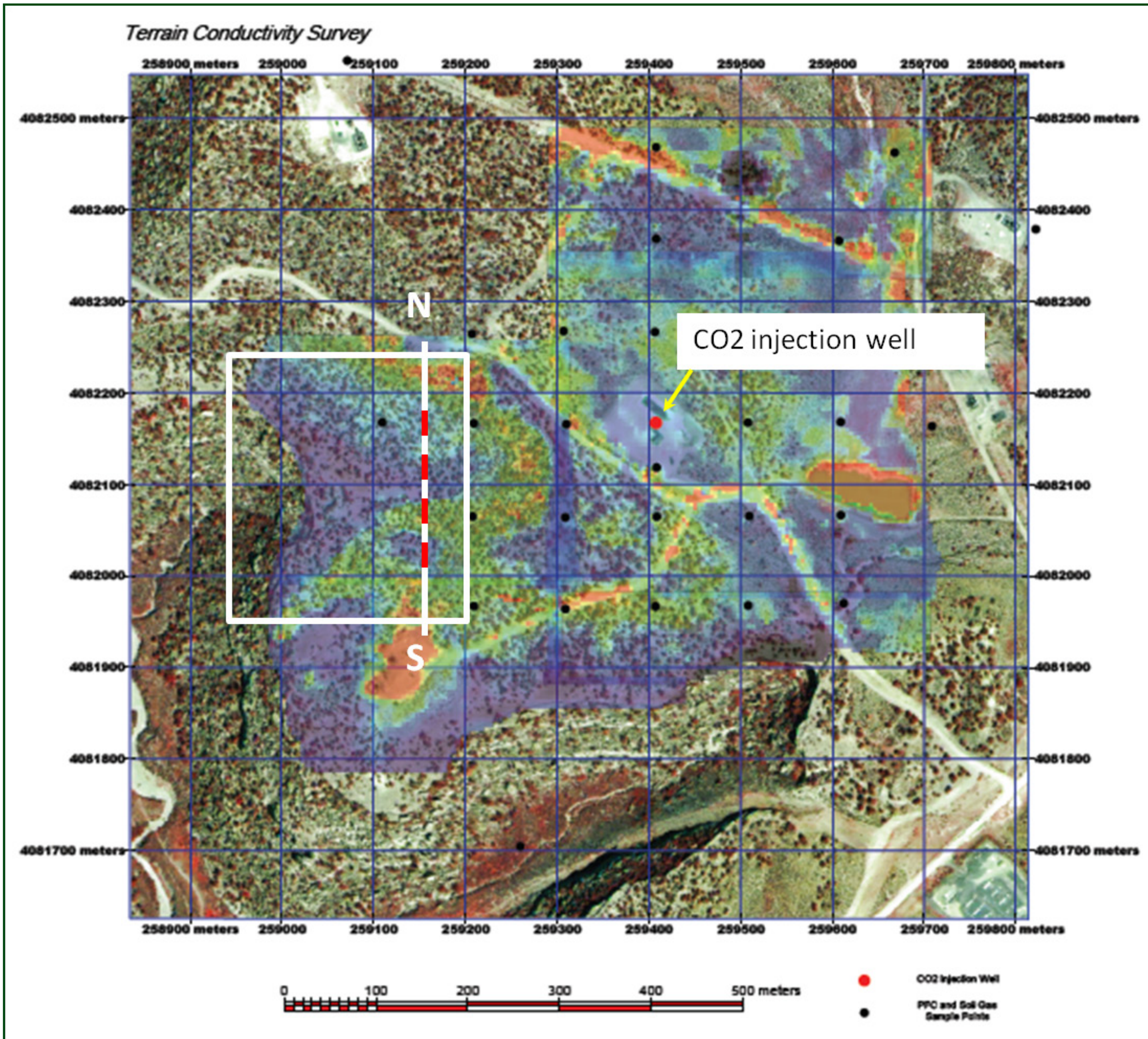

Figure 5. The GEM-2 45,030 Hz response is superimposed on a QuickBird view of the site mesa. Data collected in the area outlined by the white square are examined in detail. The bluer areas correspond to low conductivity and the green to red responses to higher conductivity.

The highest 45kHz frequency component has the shallowest depth of penetration and is fairly coherent in both surveys (Figure 9). Areas marked by lower response level are associated with well drained, mostly soil barren areas (blue areas in Figure 5).

A comparison of the quadrature components observed at all four frequencies recorded using the dual-frequency transmission reveal some consistency from frequency to frequency with exception of the lowest frequency (1,050 Hz) component. Much of the variability is expected to be associated with variations in the rock conductivity as a function of depth. Similar patterns of extracted conductivities (Figure 10) are also observed at each frequency.

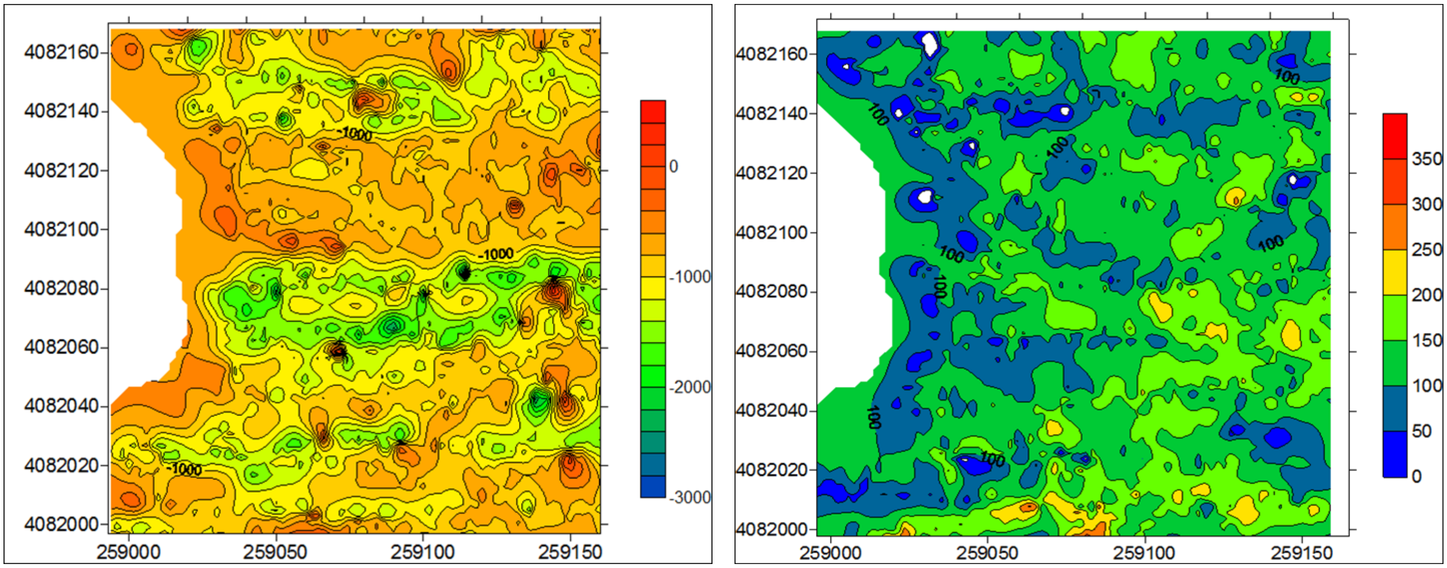

Figure 6. A) 1,015 Hz quadrature response observed in the earlier July 2007 survey. Four separate frequencies were collected simultaneously during this survey. B) The 1,015 Hz component collected in the later June 2008 survey was collected along with only one additional frequency component.

Inverse Model Study

Resistivity inversions of the four simultaneously recorded frequency responses (Figure 11) provide some insights into the near-surface resistivity distributions. The profile of soundings (Figure 11) was developed using Interpex Limited's IX1D v3 1D sounding inversion software. The modeled profile crosses the east end of the low conductivity channel-like feature that develops in this area and opens to the west

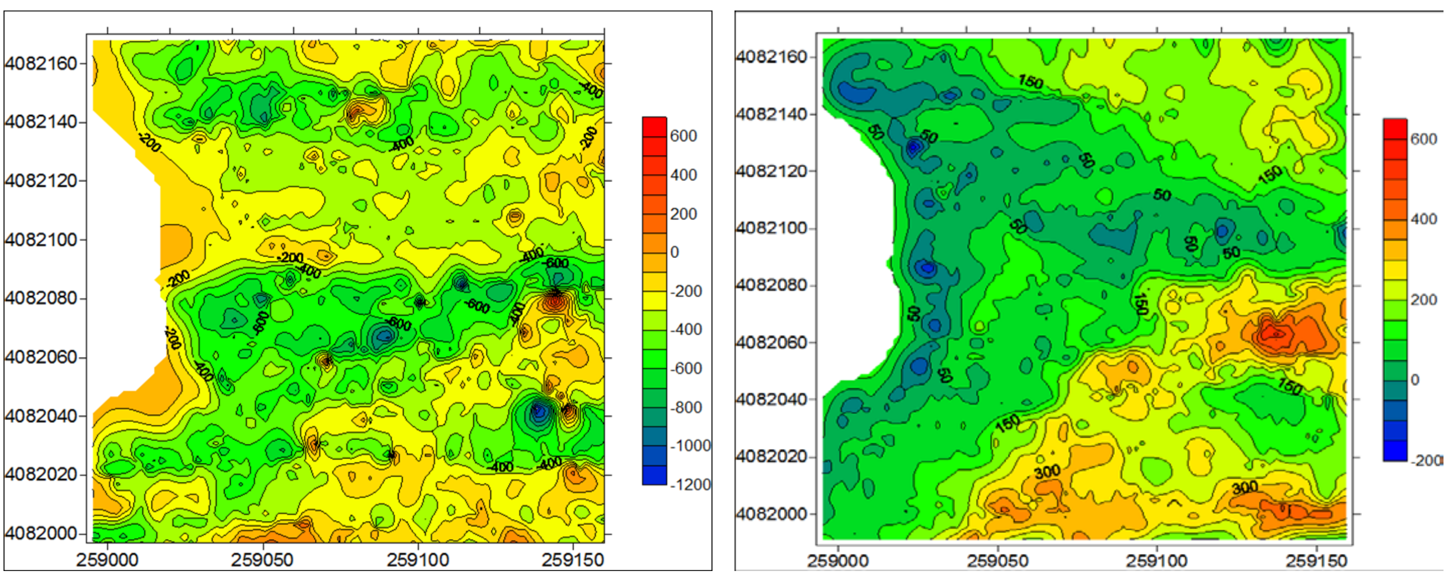

Figure 7. A) 4,110 Hz quadrature response observed in July 2007. Four separate frequencies were collected simultaneously during this survey. B) The 4,110 Hz component collected in the June 2008 survey was collected along with only one additional component.

(figures 5 and 10 D). Recorded in-phase components were nearly always negative. These observations could not be matched in the computer inversions and were typically masked during the modeling process. The results reveal shallow low resistivity (red) areas that are usually associated with thickened soil cover. These low resistivity zones are generally restricted to the upper two to three meters of the inverse model consistent with soil cover observations in the field. Although low resistivity is invariably associated with soil covered zones, the converse is not necessarily the case: some areas covered by a thick blanket of soil often have high resistivity response.

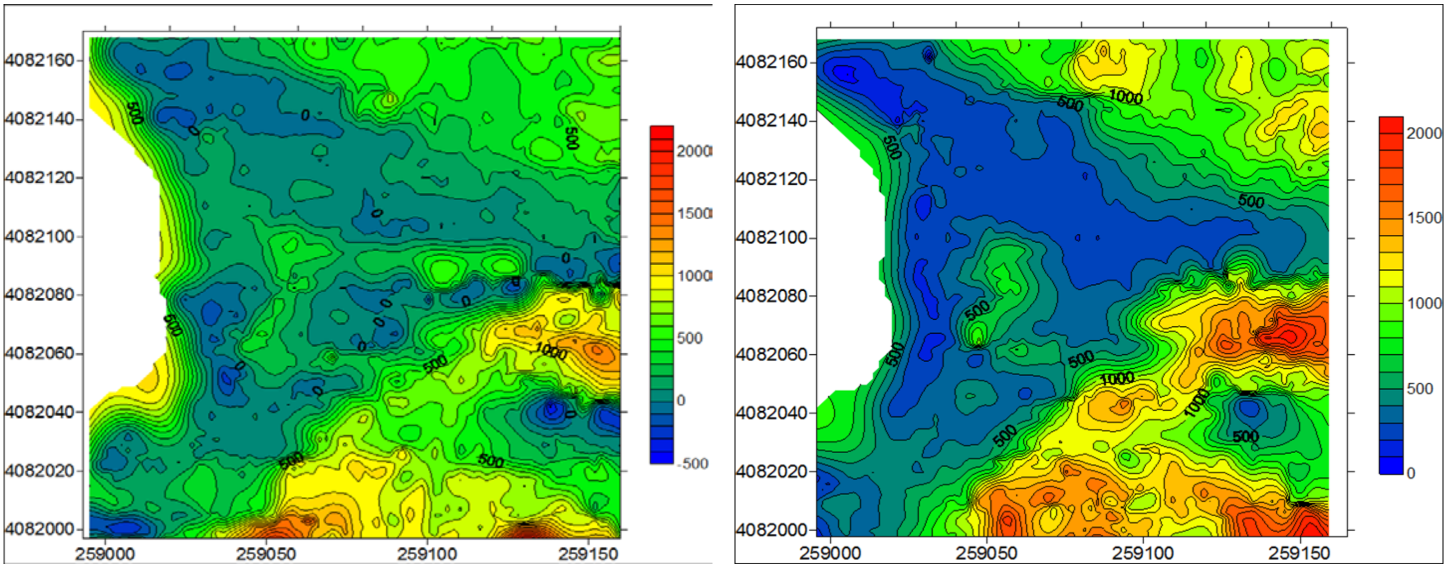

Figure 8. A) 16,890 Hz quadrature response observed in July 2007. Four separate frequencies were collected simultaneously during this survey. B) The 16,890 Hz component collected in the June 2008 survey was collected along with only one additional component.

The deeper section shows considerable local lateral variability. The inverse models lack coherence from point to point along the profile. The high resistivity surface feature near the center of the profile appears to have a high resistivity root; however, the presence of significant local variability limits certainty in this interpretation. The inverse models provide a glimpse of subsurface conditions in the area, but low signal to noise ratio, especially in the deeper parts of the model limit confidence in possible interpretations.

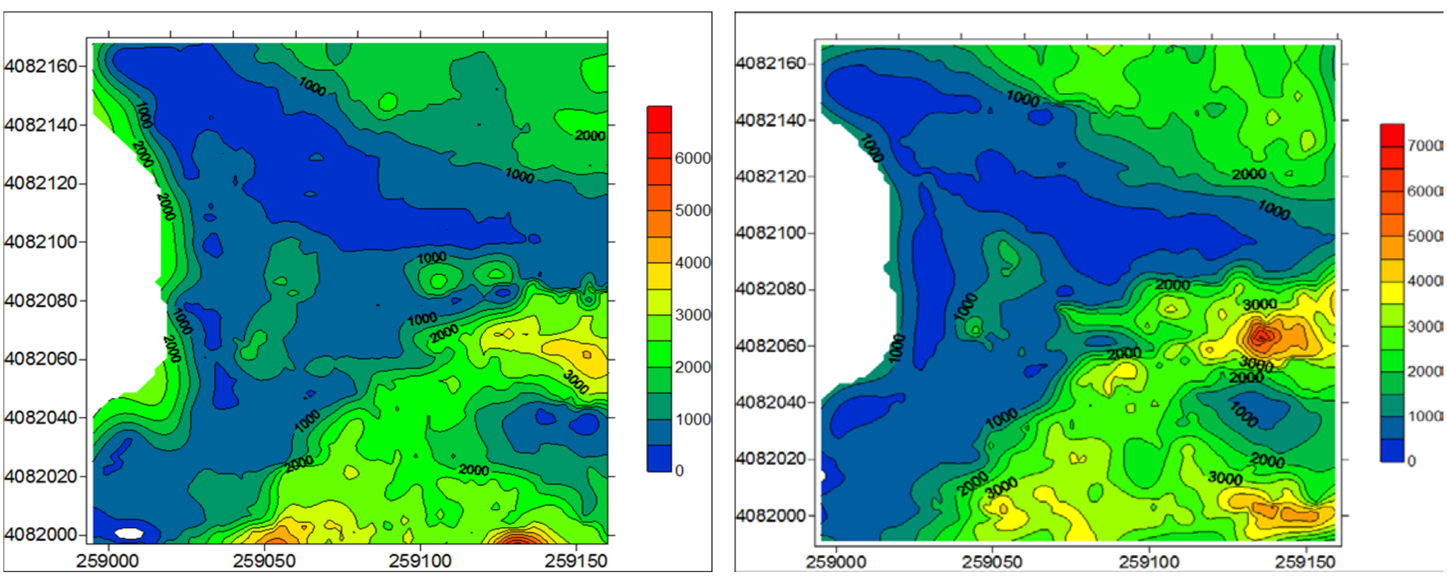

Figure 9. A) 45,030 Hz quadrature response observed in July 2007. Four separate frequencies were collected simultaneously during this survey. B) The 45,030 Hz component collected in the June 2008 survey was collected along with only one additional component.

The field area was resurveyed as noted above. Selected areas were resurveyed in two passes: one, using transmission frequencies of 16,890 Hz and 1,050 Hz; and a second pass using frequencies of 45,030 Hz and 4,110Hz Inverse models were developed following the same procedures used with the earlier four-frequency data. A slightly smaller portion of the line was modeled (see dashed red line in Figure 5). The results (Figure 12) have much better spatial coherence from sounding to sounding. The inverse models suggest that the subsurface can be divided roughly into three layers. The base of the model extends approximately 8 meters beneath the surface.

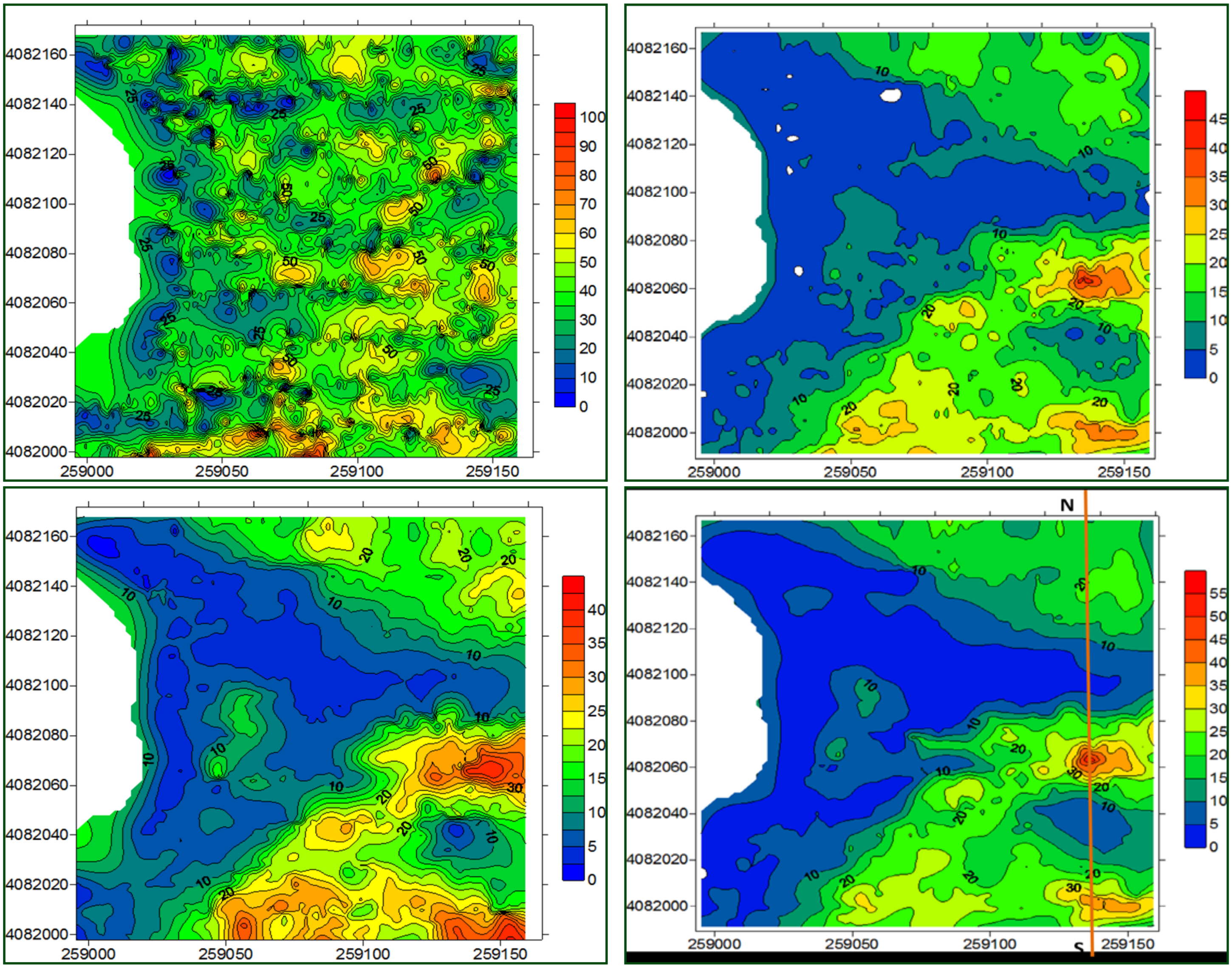

Figure 10. Conductivities extracted at each frequency. A) 1,050 Hz’ B) 4,110 Hz; C) 16,890 Hz; and D) 45,030Hz An inverse model was computed along the NS profile line (orange line) shown in D.

The comparison reveals improved signal-to-noise ratio in the model derived from data in which ground response was measured using only two transmission frequencies and illustrates improvements in the quality of the inversions obtained using the revised approach to data acquisition.

The high resistivity area that opens to the west (Figure 5 and Figure 10D) and extends to the edge of the mesa appears to consist of a headward conduit that extends from the surface down into higher resistivity less conductive areas of the sandstone that caps the mesa. Increased resistivity is interrupted by a 2-m thick zone of lower resistivity that extends from depths of about 3m to 5m subsurface.

High resistivity (low conductivity) is interpreted to represent zones of higher porosity and permeability. At the surface these areas are generally clear of colluvium. To the east toward the interior of the mesa, soil cover is scoured by narrow channels that funnel runoff out to the mesa rim. The mesa rim is generally characterized by a high resistivity (low conductivity) border that extends several tens of meters into the interior of the mesa (see Figure 5). The lower resistivity (green to red) areas generally correspond to areas of variable soil thickness across the surface of the mesa. Areas covered by soil are more likely to retain moisture from infrequent rain and snow fall. Total annual precipitation in the region is approximately 8 inches. Soil covered areas are also likely to inhibit evapotransportation of water from the underlying sandstone. Based on the inverse models we suggest that resistivity increases with depth and that the EM response is largely controlled by intervals within about 8 meters of the surface.

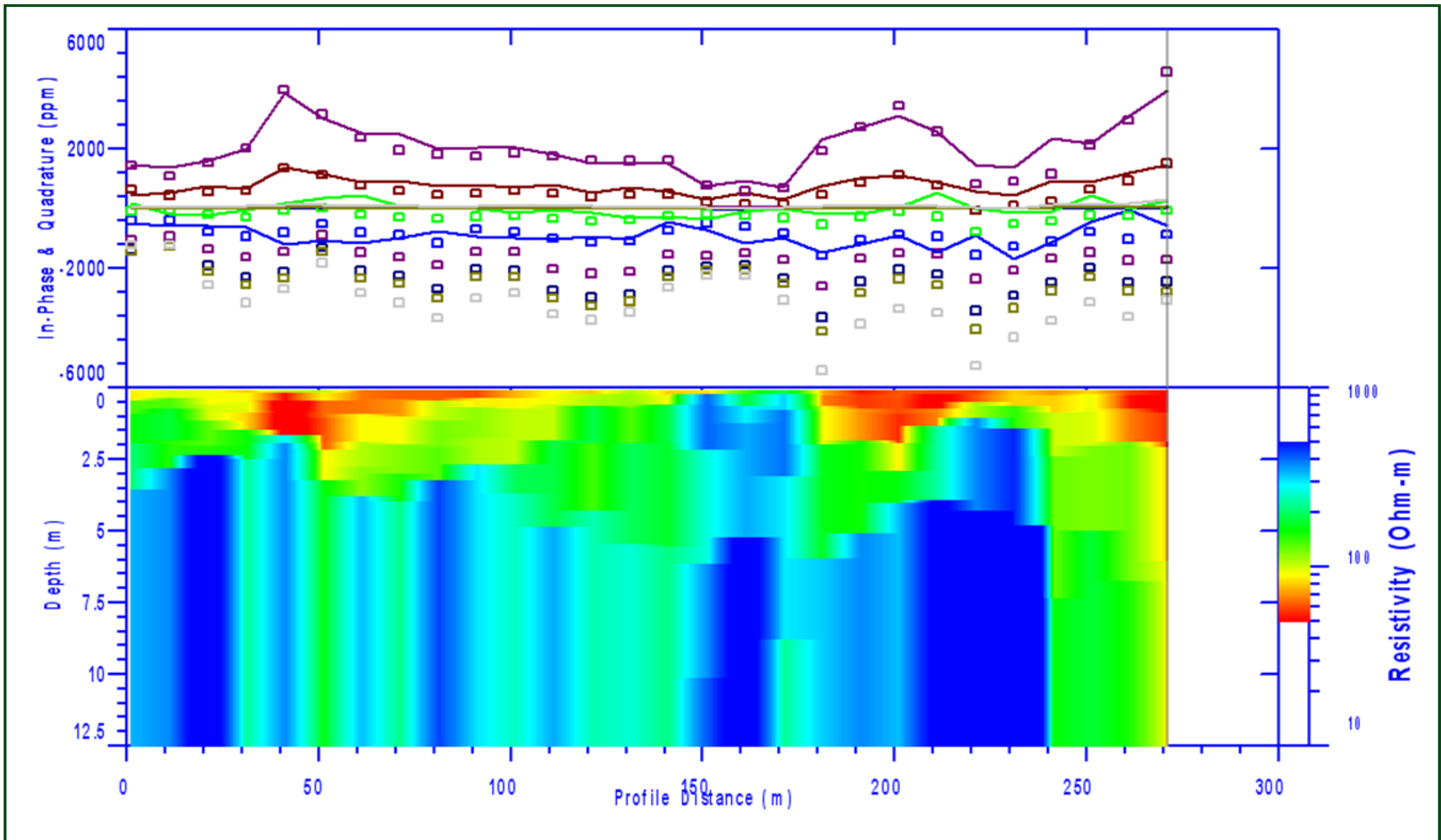

Figure 11. Inverse models portrayed in profile view. Models were developed from GEM-2 soundings made using 4 simultaneously transmitted frequencies. See Figure 5 for line location.

Summary

Approximately 70 line kilometers of EM data were collected over the Southwest Regional Partnership (SWP) Fruitland Coal Phase II pilot test site to locate flow paths in the near-surface sandstone that caps the site mesa. Identification of high porosity/permeability near-surface flow paths provides useful information to those engaged in monitoring, verification and accounting (MVA) efforts on carbon sequestration sites. This information can be used to help place tracer and soil-gas monitoring stations in areas where CO2 leakage, if it happened to occur, might re-enter Earth's atmosphere. It was felt that the quickest and most inexpensive way to identify near-surface migration pathways was to conduct terrain conductivity surveys. Data were collected using the Aeroquest Sensortech (Geophex) GEM-2 broadband EMI sensor. The instrument allows one to observe ground response simultaneously at multiple frequencies. Data are collected at a walking pace and locations are tracked using on-board GPS. In this study we present results of the site survey and evaluate different approaches to data acquisition.

The number of transmitted frequencies and transmission power are important factors to consider when conducting the broadband EM survey. In the earlier model GEM-2, the temptation was to use several frequencies in a single pass. However, as the number of transmission frequencies increased, the transmission power at individual frequencies decreased since all frequencies were transmitted simultaneously. This reduced overall signal-to-noise ratio, particularly at lower frequency. Two overcome these limitations, surveys were repeated using only two transmission frequencies to improve transmission power and signal-to-noise ratio. The initial surveys were made using simultaneous acquisition of data at four frequencies: 1,050 Hz, 4,110 Hz, 16,890 Hz and 45,030Hz Repeat surveys were then made using only two frequencies. Two passes were required to obtain the same set of measurements at all four frequencies: one pass using transmissions at 1,050 Hz And 16,890 Hz, and a second pass using frequencies of 4,110Hz and 45,030 Hz.

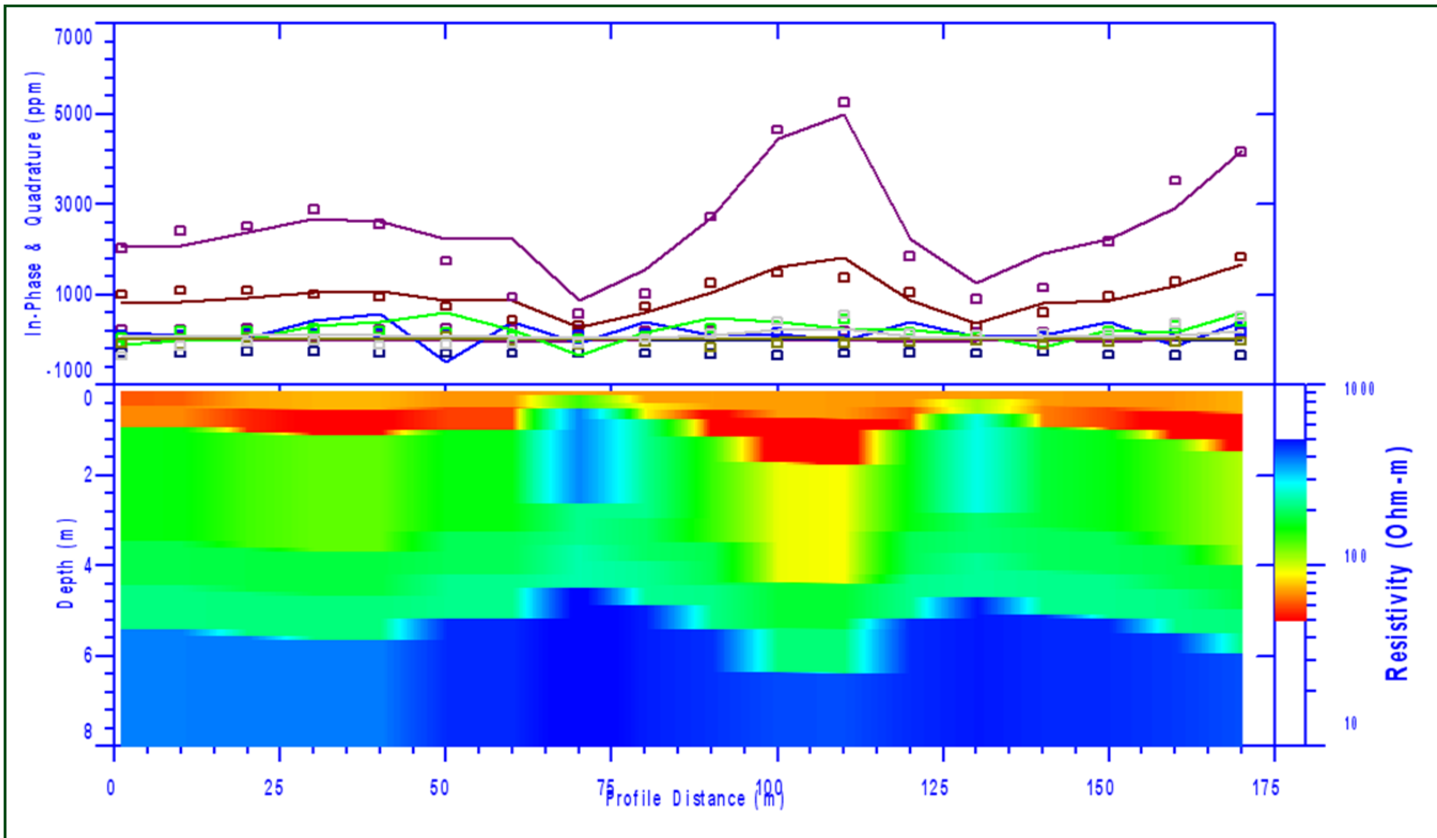

Figure 12. Layered inverse models developed along the north-south cross section. High resistivity (low conductivity) is denoted by the bluer colors; lower resistivity (high conductivity), by the orange to red colors.

Interpex Limited IX1D v3 sounding inversion software was used to derive inverse models of the GEM-2 data. Multifrequency soundings are modeled one-by-one and displayed in profile view. Inverse models derived from the initial data set contain considerable noise. Local spatial variability is significant between adjacent soundings. Models derived from data reacquired using only two transmission frequencies have much better signal-to-noise ratio.

Inverse models reveal continuous resistivity layering down to depths of about 8 meters beneath the surface. The models reveal the presence of a layered subsurface consisting of three layers that become increasingly resistive with depth (Figure 12). High resistivity (low conductivity) features in the area are interpreted as higher porosity, higher permeability conduits that facilitate drainage of precipitation and runoff through the sandstone to its base. Interpreted high permeability conduits extend from the surface down into the higher resistivity base of the layer. The sandstone lies on a relatively impermeable shale. Water accumulating at the base of the sandstone forms seeps in some areas and preferentially weathers the underlying shale. Eroded shale undercuts the sandstone. Unsupported sandstone edges begin to fracture and eventually collapse under their own weight.

Low conductivity channels (high resistivity or blue areas in Figures 11 & 12 are interpreted high permeability well drained areas in the sandstone that caps the site mesa. The rim of the mesa is characterized by a high resistivity well drained border that often extends 50 to 100 meters (~ 160 to 320 feet) into the interior of the mesa. High resistivity features are not limited to the mesa rim but are widely distributed across the mesa. The area in the vicinity of the injection well consists of a patchy distribution of low conductivity areas (Figure 5) considered to be dry and well-drained. High porosity/permeability areas are considered likely conduits for near-surface escape of any CO2 leakage that might migrate upwards through fracture zones and faults interpreted in 3D seismic coverage of the site. The low resistivity (red) areas are probably controlled by variable soil thickness across the surface of the mesa. The higher conductivity of these soil covered areas may be produced by increased water retention.

We note that newer models of the Aeroquest Sensortech GEM-2 EM sensor have been modified to incorporate step-mode operation. The newer configuration allows one to transmit each frequency at full transmission power. The requirement to repeat surveys using a smaller number of transmitted frequencies is no longer a requirement.

Acknowledgements

This technical effort was performed in support of the National Energy Technology Laboratory's ongoing research in carbon sequestration under the RES contract DE-FE0004000. We'd like to thank Bill SanFilipo and Frank Funak (Geophex) for their help and discussions concerning use of the GEM2. We'd also like to thank Dave Wildman and Donald Martello, our DOE-NETL project managers, for their support of these efforts; Bill O'Dowd, NETL project manager for the Southwest Regional Partnership; George Koperna and Brian McPherson of the Southwest Regional Partnership for their help in facilitating our involvement in the Partnership's activities on the pilot test; and Bill Akwari, Ryan Frost and Tom Cochrane of ConocoPhillips for helping to facilitate many of the onsite activities.

References

Fassett, J.E., 2000, Geology and coal resources of the Upper Cretaceous Fruitland Formation, San Juan Basin, New Mexico and Colorado, Chapter Q, in Kirschbaum, M. A., Roberts, L.N.R., and Biewick, L.R.H., eds., Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah, compiled by Colorado Plateau Coal Assessment Group: U.S. Geological Survey Professional Paper 1625-B, Version 1.0, p. Q1-Q131. [CD-ROM]. http://greenwood.cr.usgs.gov/energy/coal/PP1625B/Reports/Chapters/Chapter_Q.pdf

The University of Toledo
College of Engineering
Tenure Track Faculty Position in Geotechnical Engineering - 962235

The Department of Civil Engineering at the University of Toledo invites applications for a tenure-track Assistant or Associate Professor position in *Geotechnical Engineering*, with appointment beginning as soon as Fall 2011. *Exceptionally qualified research scholars will be considered for tenure at the rank of associate professor.* Successful candidates must have demonstrated abilities in, or evidence of outstanding potential for research and teaching undergraduate courses in Geotechnical and Civil Infrastructure, and graduate courses in Geotechnical Engineering.

The Department is particularly interested in receiving applications from candidates with the potential for a sustained research program in the areas of geotechnology at the interface with energy and the environment, and sustainable civil infrastructure. The successful applicant is expected to develop a strong externally funded research program and relevant collaborations with faculty in the Department, College of Engineering and campus community. Opportunities exist to participate in the Intermodal Transportation Institute, UT-University Transportation Center, Institute for Sustainable Engineering Materials and the Lake Erie Center. Additional resources include the Center for Materials and Sensor Characterization, University Instrumentation Center, the Polymer Institute and several programs for commercialization of new innovations. For more information about the Department and research facilities at The University of Toledo visit http://www.eng.utoledo.edu/civil/ and http://www.eng.utoledo.edu/.

Applicants must have an earned doctorate in Civil Engineering, or a closely related field. One to two years of postdoctoral or research and development experience beyond the Ph.D. degree is highly desirable. Consideration will also be given to candidates who are in the final stages of completing their doctoral programs. Licensure as a professional engineer is expected within three years of appointment. The University of Toledo is one of only seventeen U.S. public universities to offer professional and graduate academic programs in business, education, engineering, health and human services, law, medicine, nursing, and pharmacy. The University is state assisted, with an enrollment of approximately 23,000 students of which about 4,700 are graduate and professional students.

Rank and salary will be commensurate with qualifications and funds are available to establish a research program at the University. Consideration of qualified candidates will begin after January 1, 2011. The position will remain open until an appointment is made. For full consideration, applicants are encouraged to submit the following: a cover letter which addresses the position qualifications; a curriculum vitae; a one-page statement of teaching philosophy and interests; a one-page summary of research philosophy and interests; and the names, addresses, emails and telephone numbers of three references to *UT Geotechnical Engineering Faculty Search,* ***Attn****: Dr. Cyndee Gruden, Search Committee Chair, 3006 Nitschke Hall, MS 307, The University of Toledo, 2801 W. Bancroft Street, Toledo, OH 43606.* Applications will also be accepted by email at civilgeotech@eng.utoledo.edu [please include *UT Geotechnical Engineering Faculty Search* in the subject line].

The University of Toledo is an Equal Access, Equal Opportunity, Affirmative Action Employer and Educator.

CALL FOR PAPERS

Geophysics for Levee 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 levee safety. The Levee Safety issue is scheduled for publication in March 2012. The special issue editor is Dr. Maureen K. Corcoran, U.S. Army Engineer Research and Development Center. 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 levee safety risk assessment and/or remediation are sought. The issues can include woody vegetation assessment, 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 of 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 Levee Safety special issue. The deadline for submissions is February 28, 2011.

Questions may be directed to:

Special Issue Editor—Maureen K. Corcoran, Maureen.K.Corcoran@usace.army.mil
JEEG Editor—Janet Simms, Janet.E.Simms@usace.army.mil

Environmental and Engineering Geophysical Society

SAGEEP 2011 Announcement: Online Abstract Submission Site Now Open!

Nov. 19, 2010: Deadline for SAGEEP 2011 Abstracts Submissions

The Environmental and Engineering Geophysical Society (EEGS) invites you to submit an abstract for the 24th Annual Symposium on the Application of Geophysics to Engineering and Environmental Problems (**SAGEEP**) being held in historic **Charleston, South Carolina USA April 10-14, 2011**. 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. Since 1988, the symposium has been held over a 5-day period at locations throughout the United States, with approximately 150-200 oral and poster presentations, several educational short courses and workshops, numerous vendor presentations, and a commercial exhibition. A set of proceedings, comprised of technical presentations, is distributed on CD and available online. This year's SAGEEP will feature joint SEG and AGU sessions, special sessions, and courses that you won't want to miss. Check the SAGEEP web site regularly for details and updates.

Abstracts: Short, 300 words maximum abstracts are prescribed and due by Nov. 19, 2010. Submission of an abstract will constitute a commitment to attend the conference, and a $50 fee will be charged upon submission (applicable toward conference registration). Abstracts will be reviewed for both scientific relevance and absence of commercialism, and notices of acceptance or rejection will be sent in late 2010.

Submit Abstracts Online: The online abstract submission site is open! You will be asked to select a Session or General Topic under which your paper would best fit. Before submitting your abstract, review the list of Accepted Sessions and the General Topics (scroll to bottom). You may view a description for each Accepted Session (available on the abstract submission site) to aid in making that determination.

Terms of Submission: The following are the terms of submission for your abstract or poster :

- Submission of an abstract will constitute a commitment to attend the conference, and a $50 fee will be charged upon submission (applicable toward conference registration).

- Click here to pay the $50.00 abstract submission fee online - click "register for this event" to submit your credit card payment (you'll notice a new "look" to the online payment site - EEGS is converting its website and you will be entering a portal featuring the new "look" - be assured, it is the official EEGS/SAGEEP site). You may also print a form and fax or mail it to the EEGS business offices (click here for the printable submission fee payment form). These links are also available on the online abstract submission site.
- Abstracts will be reviewed for both scientific relevance and the absence of commercialism, and notices of acceptance or rejection will be sent in late 2010. Authors will then have the option of submitting an expanded abstract, if they choose.
- If the abstract is not accepted, the fee will be returned. If the abstract is accepted, but you do not register for the symposium, the fee is non-refundable. By submitting your abstract and paying the $50.00 submission fee by the Nov. 19, 2010 deadline, you are agreeing to participate in SAGEEP 2011 with an oral or poster presentation.
- Abstracts without a paid submission fee (or a postmark) by close of business Nov. 19, 2010 will be withdrawn from the conference.

- If you are from a country that requires a visa to enter the U.S., please ensure that you start the process of obtaining any required travel documents in a timely manner.

Accepted Sessions and General topics: Our call for sessions resulted in a record number of sessions that cover the spectrum of near-surface geophysics (full descriptions of the sessions can be found on the online abstract submission site):

S01: Seismic Refraction Shootout: Blind Test of Methods for Obtaining Velocity Models from First-Arrival Travel Times
S02: Migration Imaging of Near-Surface Seismic and GPR data: New developments and Case Studies (SEG sponsored)
S03: Interpretation using Multiple Methods -- An Analogy to Mathematical Boundary-Value Problems (SEG sponsored)
S04: Advances in Borehole Geophysics
S05: Development and Applications of Nuclear Magnetic Resonance Techniques for Near-Surface Investigations (AGU sponsored)
S06: New Developments in Frequency-dependent Seismic and EM Analyses for Near Surface Geophysics (SEG sponsored)
S07: Airborne Geophysics: Recent Advances and Novel Applications
S08: Educational Innovations involving Near-Surface Geophysics
S09: Geophysical Engineering for Geotechnical Site Characterization Using Seismic Surface Waves
S10: Role of Geophysics in addressing Civil, Geotechnical and

Geoenvironmental Engineering Problems
S11: Recent advances in Agricultural Geophysics
S12: Involving End Users in the Interpretation and Design of Geophysical Surveys
S13: The Use of Geophysical Data for Evidence-Based Groundwater Management (AGU Sponsored)
S14: Advances in Hydrogeophysical Monitoring
S15: Geophysics in Rivers and Streams
S16: Geophysical Studies of the Vadose Zone
S17: Application of Geophysics to Contaminant Studies
S18: Biogeophysical Signatures of Organic Rich Contaminated Sites (AGU Sponsored)
S19: Karst Geophysics Applied to Environmental and Geotechnical Problems
S20: Near-Surface Geophysics in Cold Climates (AGU Sponsored)
S21: Earthen Dams and Levees: Geophysical Reconnaissance, Exploration, and Monitoring
S22: Geophysics-Assisted Evaluation of Geotechnical/Transportation Process and Construction
S23: Application of Near-Surface Geophysics in U.S. Homeland Security
S24: Advances in Mining Geophysics
S25: Advances in Classification Methods for Military Munitions Response
S26: Advances in Military Geophysics
S27: Advances in Archaeological Applications of Near-Surface Geophysics
S28: Societal Impact of Geophysics: A Case for Underdeveloped Nations
S29: Undergraduate Poster Session
S30: Large-Scale Testing of Geotechnical and Structural Systems with NEES Equipment
S31: Large-Scale Field and Laboratory Liquefaction Experiments involving NEES Equipment Sites
S32: Funding Opportunities for Near Surface Geophysical Research
G01: General Contribution - Techniques
G02: General Contribution - Data Acquisition
G03: General Contribution - Data Processing
G04: General Contribution - Data Interpretation
G05: General Contribution - Application
G06: General Contribution

To access EEGS' website - SAGEEP 2011 - go to: http://www.eegs.org/sageep/index.html.

So don't delay - submit your abstract online at: http://www.xcdsystem.com/sageep2011/.

Optional Extended Abstracts: Authors will have the option of submitting an expanded abstract, if they choose. These optional extended abstracts may range in length from a few pages to ten or more pages, and will retain the format of previous SAGEEP proceedings (formatting guidelines are accessible from the online submission site). They must be submitted by January 14, 2011 to be included in the abstract volume that will be distributed at the conference. Reviewed/revised extended abstracts will be due on Feb. 7, 2011.

Jan. 14, 2011 Deadline for optional Extended Abstracts Submissions
Feb. 7, 2011 Deadline for revised optional Extended Abstracts

For questions concerning the abstract submission process, please contact:

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gbaker@tennessee.edu

SAGEEP General Chair
William E. Doll, PhD
DollW@battelle.org

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Web: www.eegs.org

Special Section in The Leading Edge

Application Deadline: October 15, 2010

SEG's *The Leading Edge* (TLE) will publish a special section in the February 2011 issue focusing on the near surface. This special section will not have a specific theme within the general category of near surface geophysics, so feel free to submit any article you think might be of interest to the broad readership of TLE. Collectively, the near-surface geophysical community solves an amazing number of shallow subsurface problems using a wide range of geophysical tools. It is our hope that we can provide the TLE readership with a flavor of this diversity in the February 2011 issue. This will be the only issue of TLE during 2011 specifically targeting near-surface topics, so don't let the October 15, 2010 submittal deadline get away from you, keep it on your calendar. If you have any comments, questions, or would like to submit a paper for consideration, please contact Rick Miller rmiller@kgs.ku.edu or Greg Baker gbaker@tennessee.edu.

Funding Available for Environmental R&D

Application Deadlines: January 6, 2011 (non-federal sector) and March 10, 2011 (federal sector)

ARLINGTON, VA, October 28, 2010 - The Department of Defense's (DoD) Strategic Environmental Research and Development Program (SERDP) is seeking to fund environmental research and development proposals. SERDP is DoD's environmental science and technology program, planned and executed in partnership with DOE and EPA, with participation by numerous other federal and non-federal organizations. The Program invests across the broad spectrum of basic and applied research, as well as advanced development. The development and application of innovative environmental technologies will reduce the costs, environmental risks, and time required to resolve environmental problems while, at the same time, enhancing and sustaining military readiness.

Proposals responding to focused Statements of Need (SON) in the following areas are requested:

- Environmental Restoration - Research and technologies for the characterization, risk assessment, remediation, and management of contaminants in soil, sediments, and water.
- Munitions Response - Technologies for the detection, classification, and remediation of military munitions on U.S. lands and waters.
- Resource Conservation and Climate Change - Research that advances DoD's management of its natural and cultural resources and improves understanding of climate change impacts.
- Weapons Systems and Platforms - Research and technologies to reduce, control, and understand the sources of waste and emissions in the manufacturing, maintenance, and use of weapons systems and platforms.

Proposals responding to the Fiscal Year (FY) 2012 SONs will be selected through a competitive process. Separate solicitations are available to federal and non-federal proposers. The SONs and detailed instructions for federal and private sector proposers are available on the SERDP web site at http://www.serdp-estcp.org/Funding-Opportunities/SERDP-Solicitations.

The Core SERDP Solicitation provides funding in varying amounts for multi-year projects. For the Core Solicitation, PRE-PROPOSALS FROM THE NON-FEDERAL SECTOR ARE DUE BY THURSDAY, JANUARY 6, 2011. PROPOSALS FROM THE FEDERAL SECTOR ARE DUE BY THURSDAY, MARCH 10, 2011.

SERDP also will be funding environmental research and development through the SERDP Exploratory Development (SEED) Solicitation. The SEED Solicitation is designed to provide a limited amount of funding (not to exceed $150,000) for projects up to one year in duration to investigate innovative approaches that entail high technical risk or require supporting data to provide proof of concept. ALL SEED PROPOSALS ARE DUE BY THURSDAY, MARCH 10, 2011.

LEARN MORE ABOUT FUNDING AVAILABLE THROUGH SERDP:

TWO OPPORTUNITIES, TWO DIFFERENT TIMES!

Participate in a webinar on “SERDP Funding Opportunities” conducted by SERDP and ESTCP Director Dr. Jeffrey Marqusee on November 16, 2010, at 12:00 p.m. EST. This “how to play” briefing will offer valuable information for those who are interested in new funding opportunities with SERDP. During the online seminar, participants may ask questions about the funding process, the current SERDP solicitation, and the proposal submission process. Pre-registration for this webinar is required. To register, visit http://webinars.serdp-estcp.org. If you have difficulty registering, please contact Mr. Jon Bunger in the SERDP Office at *jbunger@hgl.com* or by telephone at 703-696-2126.

AND

Join us in person for the Partners in Environmental Technology Technical Symposium & Workshop, November 30 - December 2, 2010, in Washington, DC, where SERDP and ESTCP Director Dr. Jeffrey Marqusee will present a Funding Opportunities Briefing and Q&A session on Thursday, December 2, 2010 at 12:15 p.m. EST. This presentation will offer valuable information for those who are interested in SERDP and ESTCP funding opportunities as well as answer questions about the funding process, proposal submission, and the current FY 2012 SERDP solicitation and upcoming FY 2012 ESTCP solicitation. To learn more about the Symposium or to register for this event, visit *http://www.serdp-estcp.org/symposium*.

Near-Surface Geophysics Best Usages and Limitations Survey

There is a newly formed National Academy committee on “Underground Engineering for Sustainable Development” (http://www8.nationalacademies.org/cp/projectview.aspx?key=49215). It is important that the discipline of engineering geophysics be represented in the report that will be produced from that committee.

You have an opportunity to put in your two cents. Given the basic premise that geophysical methods are important to the future development of underground space for infrastructure particularly in urban environments, one of the committee members, Dr. Priscilla Nelson from NJIT (pnelson@njit.edu), would like to make sure that geophysical methods are included in the report together with their best usages and limitations, and to identify opportunities for R&D and education that would make the methods even more useful.

We ask the *FastTIMES* readers to fill the attached Excel spreadsheet and return it to us with the promise to echo the results back to you so that we can learn from ourselves. We invite your input on:

- how geophysics is best used (and/or not used) for site characterization and non-destructive testing associated with underground infrastructure projects - during construction and through the life cycle
- what research needs are there
- what ought we to be doing regarding our education curricula and the need for engineers and geophysics applications folks to get together to bring content to undergraduate and graduate students
- and similar thoughts about what is warranted regarding continuing education of practitioners.

Please email your response to:

Soheil NAZARIAN
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University of Texas at El Paso
nazarian@utep.edu

	Borehole Logging	Crosshole Tomography	Down/Up Hole Seismics	GPR	Seismic Refraction	Seismic Reflection	SASW MASW	Conductivity	Resistivity	Gravity	Magnetics	LIDAR	Photo-grammetry	SAR	InSAR DInSAR PSI	Other Methods
Subsurface Interrogation																
Geomaterial property evaluation (e.g., small-strain stiffness, correlations with strength and other index and material properties including soil consistency, rock mass properties, RΘD and fracture frequency, characteristics of rock discontinuities)																
Top of rock																
Water table location																
Stratigraphy – geologic unit boundaries and orientations, type of rock																
Structure – joints, faults, shear zones																
Zones of contamination																
Information on spatial variability, uncertainty																
Identifying obstructions (e.g., from previous construction or from nature – boulders, etc.)																
Identifying archeological artifacts																
Characterization of existing surface or underground structures and facilities																
In situ stress in rock, hydraulic fracture testing/monitoring																
During Construction																
Probing ahead of the excavated face																
QA on lining placement (e.g., thickness, concrete quality)																
Damage zone into excavated walls																
Deformation measurements (e.g., resulting from overstress and/or stress redistribution, ground convergence – including LIDAR and photogrammetric applications?)																
Vibration monitoring																
Compaction (e.g. for backfilling, pavements)																
Grouting monitoring																
Freezing monitoring																
During Operations/Maintenance																
Lining deterioration (both of the lining material and lining surfaces/spalling)																
Corrosion																
Finding voids																
Monitoring rehabilitation (e.g., relining, surface treatments, grouting, deformation monitoring)																
Looking for changes in geomaterial properties behind the lining																
Other Applications																
Any Other Application																

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.

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

NovCare 2011 - Workshop on Novel Methods for Subsurface Characterization and Monitoring: From Theory to Practice

May 9-11, 2011, Ocean Edge Resort, Brewster, MA

As societal concerns over sustainability of groundwater resources mount, and to address pressing issues of groundwater quality and quantity, the environmental research community increasingly finds itself in need of investigation methods that have high accuracy and resolution across a range of spatial and temporal scales. Ideally, such methods should be able to identify, quantify, and parameterize relevant physical and biochemical processes through space and time.

In recent years, several new technologies have been developed for cost-effective, minimal-disturbance, and high-resolution subsurface characterization and monitoring. Most of these methods, however, are not yet widespread. To share insights and knowledge, and to identify key areas for future research and development we announce a workshop to bring together interested stakeholders from a broad range of areas, including research, technology development, consultancy, and government.

The three-day workshop, sponsored by the Army Research Office, will provide a rare opportunity for participants to explore, experience, and discuss the latest science on subsurface characterization and monitoring. Workshop activities include plenary and poster sessions with invited and selected speakers, a social event, and a field trip to the famous Cape Cod Tracer studies on Otis Air Force Base. At this site, vendors will be on hand to present field demonstrations of their latest technologies.

Thematic areas for the conference are: subsurface transport monitoring, contaminant remediation, stream-aquifer interactions, and watershed characterization. Relevant technologies include: direct-push characterization tools, surface and borehole geophysics, adaptive & wireless sensor networks, geotechnical methods and sonic drilling, novel sensing devices, and tracer and other hydraulic testing methods.

Logistics

The workshop will be held at the Ocean Edge Resort, located on Cape Cod, MA, with easy access from Boston and close to the proposed demonstration site on Otis Air Force Base. Accommodation for attendees will be at the conference facilities.

A first call for abstracts will be distributed in November, 2010. More information can be found on http://www.novcare.org.

Organizing committee:

- Drs. David Hyndman, Remke van Dam - Michigan State University
- Drs. Jim Butler, Geoff Bohling – Kansas Geological Survey, Univ. of Kansas
- Drs. Peter Dietrich, Georg Teutsch – Helmholtz Center for Env. Research (UFZ)
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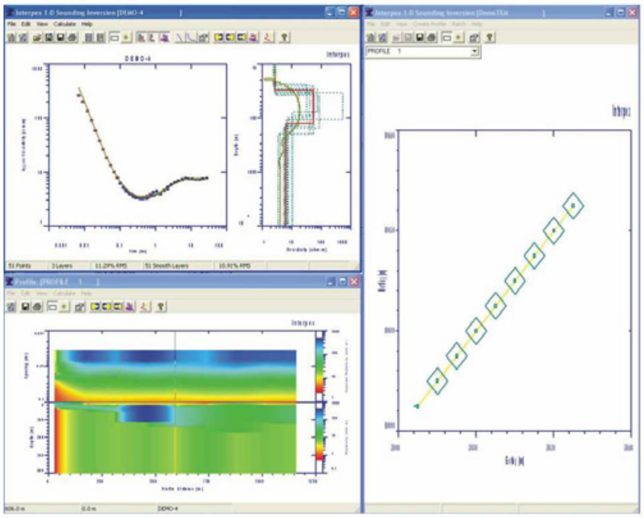

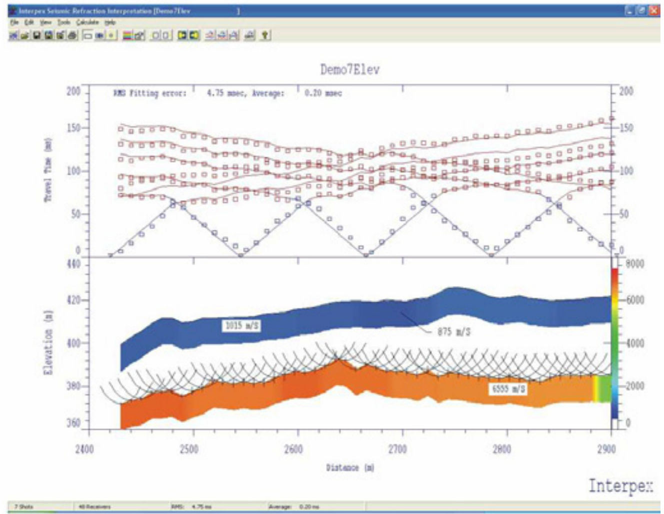
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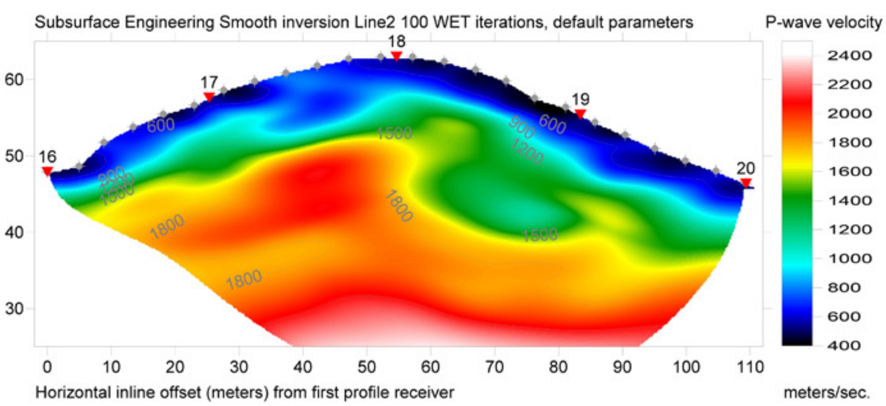
Subsurface Engineering Smooth inversion Line2 100 WET iterations, default parameters
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Industry News

FastTIMES presents articles about commercial products for use in near geophysics investigations. Corporate sponsors are invited to send the editors descriptions of new products for possible inclusion in future issues.

Javelin: A Slimhole and Microhole NMR Logging Tool

David O. Walsh, Elliot Grunewald, Peter Turner and Igor Frid, Vista Clara Inc., Mukilteo WA, USA (www.vista-clara.com)

Nuclear magnetic resonance (NMR) logging tools have been widely used in the oil industry for more than two decades. NMR logging tools provide direct detection and measurement of liquid forms of hydrogen, including water and hydrocarbons, and can also provide information on the pore-scale properties and permeability of fluid bearing formations. For these reasons, NMR logging has long held promise as a potentially powerful tool for use in hydrogeology and near-surface environmental investigations.

To date, the high cost and large size of existing oilfield NMR logging tools has greatly limited their use in hydrological and environmental applications. Existing oilfield NMR logging tools are designed to operate at depths up to 6 miles, at temperatures up to 150 C and pressures up to 20,000 psi. An exemplary state-of-the-art oilfield NMR logging tool is the Schlumberger MR Scanner tool, which is approximately 33 feet long, weighs 1200 lbs, and can operate in a minimum borehole diameter of 5.875 inches. Many groundwater observation wells are constructed with diameters less than 5 inches, and a very large number of environmental investigation wells are constructed using 2-inch diameter PVC casing. Although existing NMR logging tools offer state-of-the-art measurements and interpretations, the costs of oilfield NMR logging services have remained prohibitive for the majority of potential applications in groundwater and environmental investigations.

Javelin Design and Specifications

Vista Clara recently developed, field-tested and commercialized a low-cost, small-diameter NMR logging tool that we call Javelin. The design objective was to develop an NMR tool that could operate in PVC-cased or open boreholes as small as 2 inches in diameter, and to a depth of 200 meters, while maintaining a reasonably low cost that is essential for the widespread use of NMR logging in hydrology. The small diameter NMR performance objectives were achieved through innovations that minimize the size and maximize the sensitivity of the downhole electronics. The cost objective was achieved by relaxing or eliminating many of the expensive engineering solutions that are required for logging oil reservoirs at depths of 6 miles, but are unnecessary for logging groundwater aquifers in the upper 200m.

The Javelin NMR logging system is shown in Figure 1 and consists of:

1. A shock-mounted surface electronics unit, controlled by a laptop PC.
2. A cable winch with up to 200 m of custom NMR logging cable.
3. Various connectorized downhole NMR probes, with diameters from 1.67 inches to 3.5 inches.

The 1.67 inch diameter borehole NMR probe (Javelin Micro, shown in Figure 1) has a length of 7 feet, a weight of 25 lbs and vertical resolution of 1.0m. The 3.5 inch diameter borehole NMR probe (Javelin Slim) has a length of 4 feet, a weight of 35 lbs and a vertical resolution of 0.5m. A 2.5 inch diameter NMR probe (Javelin Mole, shown in Figure 1) was designed specifically for deployment by a Geoprobe direct push machine. The entire system is powered by 110V 60Hz AC, which can be supplied by a generator or local AC power if available. The entire system weighs less than 400 lbs and is easily transported in the back of a Ford F-150 pickup truck.

Figure 1: Javelin system components including rack-mounted surface electronics, cable winch with up to 600 feet of custom cable, and various connectorized downhole NMR probes. The 2.5" diameter Geoprobe ® deployable probe and the 1.67" diameter borehole probes are shown in the foreground.

The Javelin downhole probe includes a magnet and sensor coil assembly that is similar in concept to the original Numar design (Miller 2001). The tool senses the NMR response in a thin (~ 2mm thick) cylindrical shell that surrounds the center of the tool, as depicted in Figure 2. The Javelin tool is presently operated in the frequency range of 250 kHz to 300 kHz. This frequency range was selected so as to make the diameter of the sensitive region as large as possible to avoid the disturbed annular region that can develop when drilling wells in unconsolidated sediments. As a result, the sensitive region for the 3.5 inch diameter tool is located at a radial distance of approximately 7.5 inches from the tool center; the 1.67 inch diameter probe has a radial depth of investigation of approximately 5.5 inches. The Javelin tool also can be operated in dual frequency mode to sample two concentric cylindrical"shells" in the same logging cycle.

In field work to date, we have operated the Javelin tool at logging speeds of 2 – 10 m/hr, with resulting vertical resolution of 0.5 m. This is considerably slower than typical oilfield logging tools, and is a consequence of both the smaller tool diameter and the lower operating frequency, both of which lower the theoretical signal to noise ratio. Again, the design tradeoffs were made to satisfy the requirements of logging groundwater aquifers in the top 200m, where costs related to "rig time" are non-existent and where a large percentage of wells are less than 5 inches in diameter and drilled in unconsolidated sediments.

NMR Logging Results

Field tests of the 3.5 inch diameter Javelin tool were conducted at several research sites across the United States in the spring of 2010. Here we present logging results from two different study sites, demonstrating the capabilities of the Javelin system.

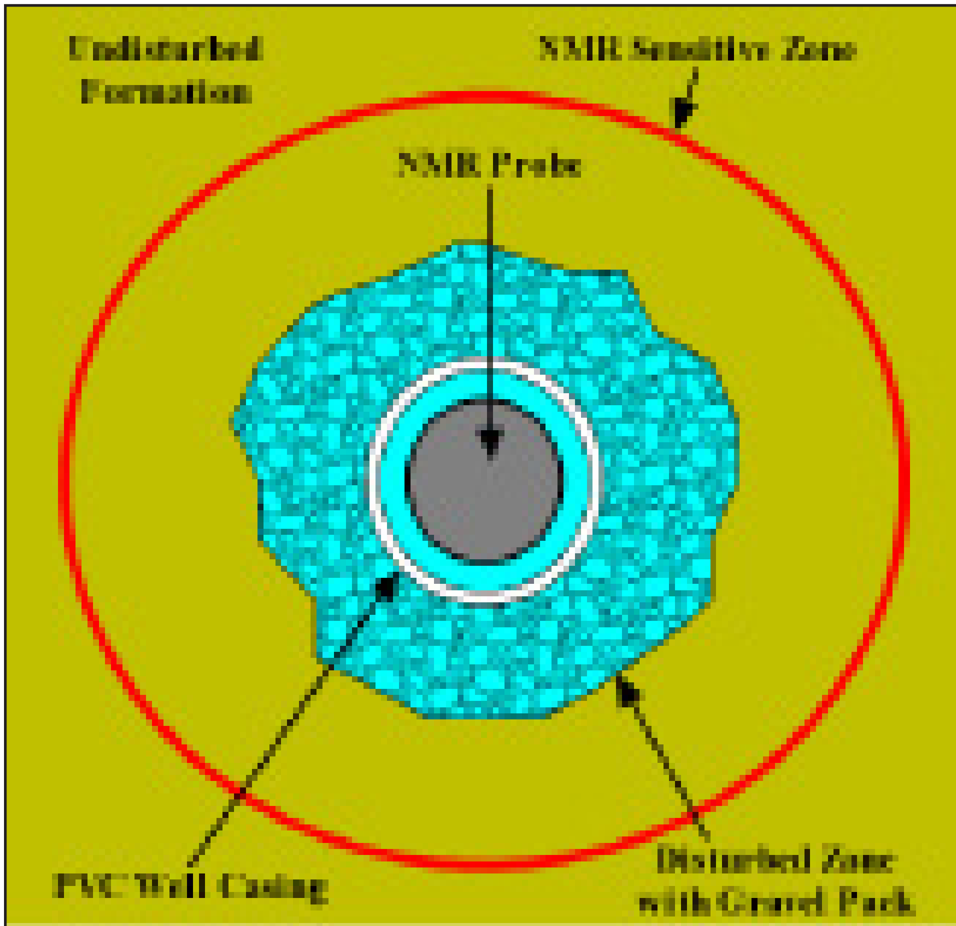

Figure 2: The NMR sensitive region of the Javelin tool resides in a thin cylinder surrounding the center of the tool. This sensitive region is ideal for detecting water in the undisturbed aquifer or formation, and avoids detecting water in the drilling-disturbed annular region. The diameter of this NMR sensitive cylinder varies from 11 inches to 16 inches, depending on the tool.

With cooperators from the US Geological Survey, Javelin NMR logs were collected in several wells at the Massachusetts Military Reservation (MMR) near Cape Cod, Massachusetts. One aim of contaminant studies at MMR is to characterize and delineate fine-grained silt layers interbedded in a mostly sandy aquifer. These silt layers are expected to have a low permeability, and thus are likely to influence the movement of groundwater and migration of contaminant plumes.

An example Javelin log from the MMR site is shown in Figure 3; this log was acquired in a 4 inch diameter PVC-cased well to a maximum depth of 98 m. The standing water level in the well was 20 meters below ground surface. Shown in the left-most panel is the T2 decay-time distribution of groundwater at each depth interval. Numerous NMR studies have demonstrated the T2 decay time is most strongly correlated with pore size (e.g. Timur, 1969; Brownstein and Tarr 1979). Water that is free to flow in large pores exhibits long T2, while water that is bound in small pores exhibits short T2. Throughout the majority of the logged interval, T2 values are long, reflecting a high fraction of mobile water in sandy materials. Within specific intervals (65 m, 70–74 m, and 82–83 m), however, observed T2 values are significantly shorter. These intervals, which show an increase in bound water content and a decrease in mobile water, indicate the presence of low permeability silt layers that are likely to be important factors controlling contaminant transport. The NMR log also indicates another possible “hanging silt” layer in the unsaturated zone at a depth of 12m.

Three different estimators of hydraulic conductivity were applied to the Javelin NMR data from the Massachusetts Military Reservation. These are plotted in Figure 4. All three permeability estimates indicate large decreases in hydraulic conductivity at 65m, 70 – 73m, and 81 – 82m. We would strongly recommend that these NMR-derived permeability estimates be calibrated with local direct permeability measurements before being used for quantitative analysis of aquifer permeabilities.

In cooperation with the Kansas Geological Survey, Javelin logs were acquired at the Geohydrologic Experimental and Monitoring Site (GEMS), near Lawrence, Kansas. The geologic stratigraphy at this site has been well-characterized by prior studies and is known to be comprised of discrete layers of sand, clay, and silt with variable thickness. An example Javelin log from the GEMS site is shown in Figure 5; this log was collected in a 4” PVC-cased well to a total depth of 20 m. The log distinguishes a sharp transition from a silt layer (with short T2) above 11 m to sand (long T2) below 11 m. The location of this transition and spatial variations in hydraulic conductivity are consistent with auxiliary hydrogeologic data collected previously at this well site (Butler, 2005).

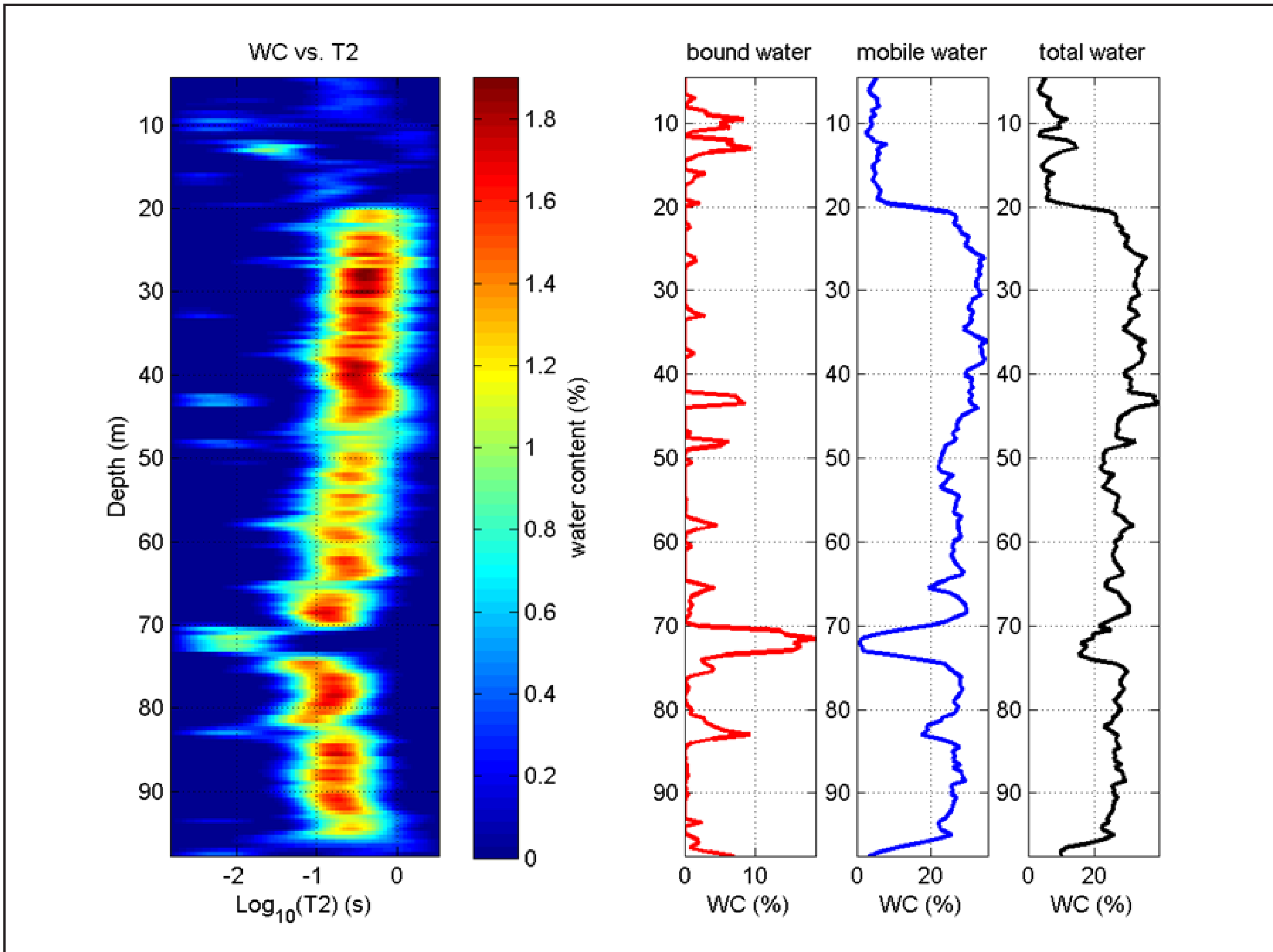

Figure 3: Javelin NMR water content log from a 4 inch PVC-cased well at the Massachusetts Military Reservation, Cape Cod MA, May 2010.

While these results primarily confirmed known hydrogeologic information, the logs also provided new and unexpected information to scientists at GEMS. The standing water level in the well at the time of logging was 4m; however, significant amounts of mobile water were detected at depths shallower than 4 m where the geology was expected to be silty and unsaturated. Further investigation revealed that the grout surrounding the upper portion of the well had become cracked over time by weathering. It is now suspected that these long-T2 signals most reflected the presence of pooled water within these large cavities and cracks in the grout (the site had been inundated with water due to large rain storms

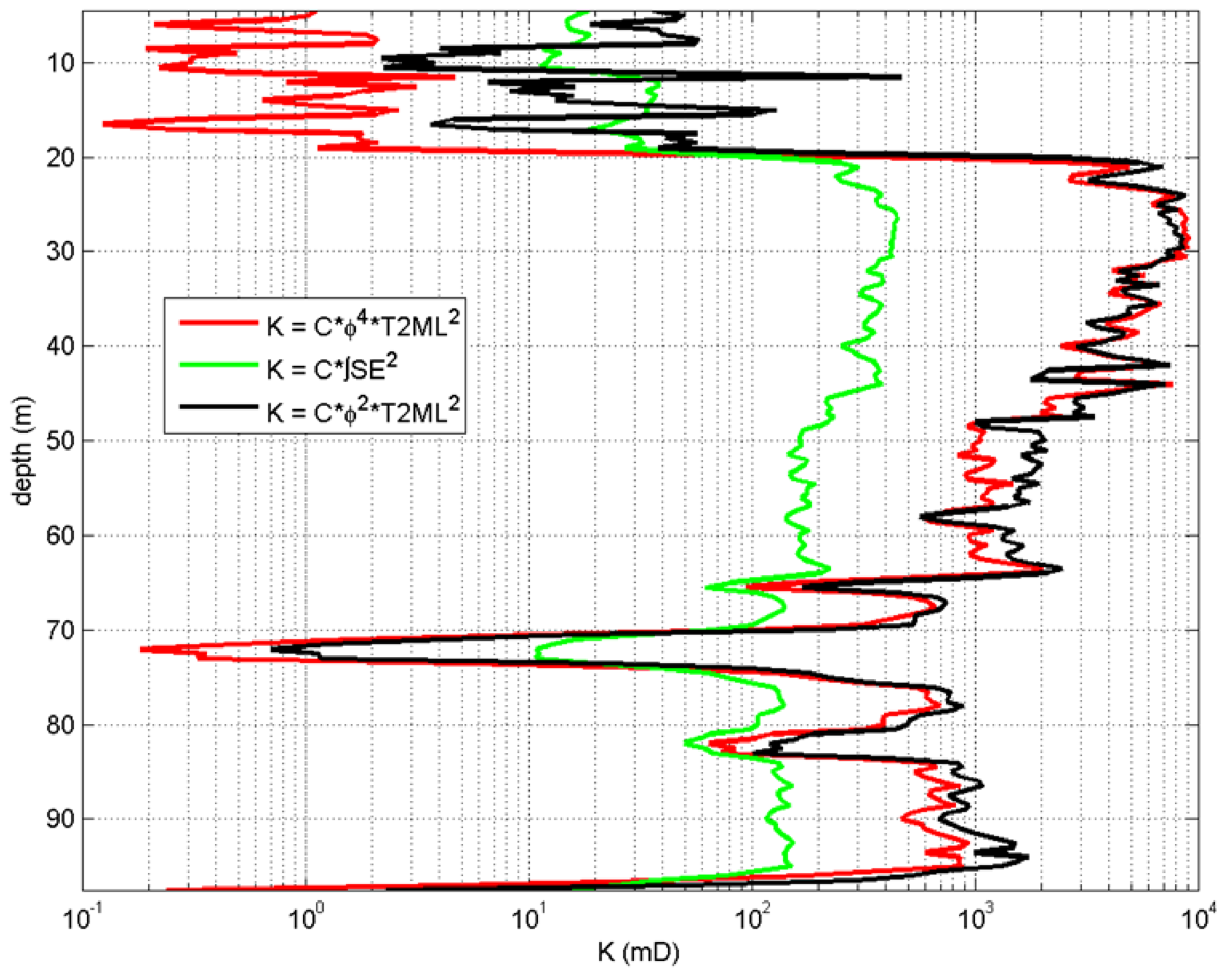

Figure 4: Three different permeability estimators applied to the Javelin NMR log data from the 4-inch PVC well at the Massachusetts Military Reservation.

a few weeks before the data were acquired). This finding illustrates that Javelin measurements may also be informative in assessing the integrity of subsurface engineering, such as grouting or back-fill.

Acknowledgements

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The authors thank the US Geological Survey and the Kansas Geological Survey for their generous assistance in obtaining the NMR logging data presented in this article.

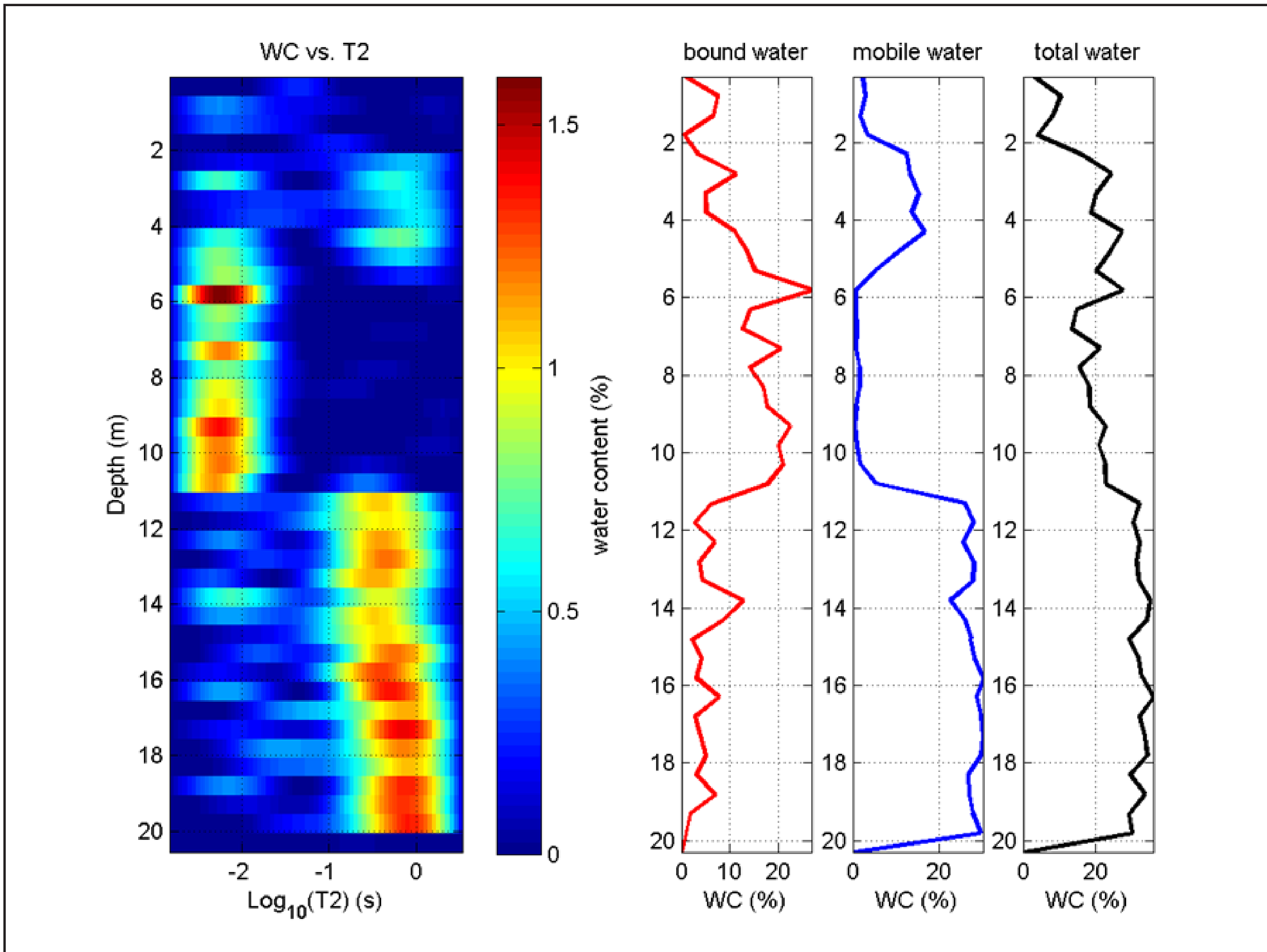

Figure 5: Javelin NMR water content log from a 4 inch PVC-cased well at the Geohydrologic Experimental and Monitoring Site (GEMS), Lawrence, Kansas, April 2010.

References

Brownstein, K. R., and C. E. Tarr, 1979, Importance of classical diffusion in NMR studies of water in biological cells: Physical Review A, 19, 2446–2453.

Butler, J.J., Jr., Hydrogeological methods for estimation of hydraulic conductivity, in Hydrogeophysics, edited by Y. Rubin and S. Hubbard, Springer, The Netherlands, 23-58, 2005.

Miller, M. N., 2001. “NUMAR and NUMALOG Overview”, Concepts in Magnetic Resonance, Vol. 13 (6), 379 – 385, 2001.

Timur, A., 1969, Pulsed nuclear magnetic resonance studies of porosity, movable fluid, and permeability of sandstone: Journal of Petroleum Technology, 21, 755-786.


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SAGEEP Short Course Handbooks

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	0028	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
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	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
		EEGS T-shirt (X-Large) Please circle: white/gray	$10	$10
		EEGS Lapel Pin	$3	$3
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