CREWES News

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www.crewes.org

Reaching Out to You

At CREWES, one of our most frequent points of discussion, apart from ongoing technical issues, is about improving our interaction with our sponsors. Of course our annual meeting is a great time for interaction, but we realize that only a small fraction of the geophysicists employed in sponsoring organizations can attend our meeting. Ideally those attending the meeting will carry back useful information to their colleagues, but the reality of workplace pressures limits this process. We also try to make our website as useful as possible and we hope this newsletter also contains some valuable information. However, we recognize that we can still do better and so have made several initiatives recently.

For the 2009 Research Report (released in last November) we included for the first time a Summary Book with colorful one-page abstracts of each of the 77 technical papers in the report. The Summary Book can be accessed on our website under the "Research Reports" link and then clicking on Summary Book. Each one-page expanded abstract is hyperlinked to the corresponding technical report and the link can be followed by clicking on the title of the abstract. We encourage you to use this Summary Book to access our work.

Many of us are willing and able to visit your workplace and speak about our research. On our website under the "For our Sponsors" heading is a link titled "Talks & Courses". This will take you to a listing of presentations, grouped by speaker, which we are willing to give on short notice.

Additionally, we have recently put together a PowerPoint summary of current research and project status. The research slides in this summary are a group effort containing contributions from the entire project. This allows us to give a comprehensive overview of CREWES on very short notice. This has proven a valuable internal exercise for us and it has also been very effective in bringing our sponsors a glimpse of our latest activities. In recent presentations using this tool, I have received many positive remarks from sponsor scientists who are startled to learn of the breadth and depth of our research.

We would welcome a chance to present this in your office.

Finally, we are always looking for new ways to increase our communication. The Summary Book mentioned above was actually suggested by a sponsor and we are grateful for it.

If you have any suggestions for better communication, or for research topics for us, please don't hesitate to contact me.

Gary Margrave
Director

Left: Rob Ferguson and his Grad Students: Back L-R Akshay Gulati, Roohollah Askari, Marcus Wilson. Front (L-R): Mahdi Al-Mutlaq, Rob Ferguson, Vanja Milicevic, Diane Lespinasse. (missing Ritesh Sharma). See page 3 for more info.

Inside this issue:

Meet the New CREWES Students

Chris Bird
M.Sc. Student
(Supervisors: Kris Innanen)

Chris received his B.Sc. degree in Geophysics from the University of Saskatchewan in 2007. He worked as a seismic processor for Key Seismic Solutions in Calgary from 2007 until 2009. Chris enrolled in Graduate Studies at the University of Calgary and joined the CREWES project in January 2010 to pursue a Master's degree. His interests include seismic inversion, attenuation, processing and interpretation.

Jean Cui
Ph.D. Student
(Supervisor: Larry Lines)

Xiaoqin (Jean) Cui earned an M.Sc. Geophysics science (China University Of Mining & Technology). She has seismic data processing experience via posting in China and Calgary. She has worked in the industry since 1987, and has worked with CGGVeritas since 2006. Jean started her Ph.D. in January 2010 at the University of Calgary and is working with both CREWES and CHORUS in the department of Geoscience. Her research interests are in fracture analysis.

Li Lu
M.Sc. Student
(Supervisor: Gary Margrave)

Li Lu received a B.Sc. Geophysics (1989) from the DaQing Petroleum Institute, P.R. China and she worked for CNPC (China National Petroleum Company) for 10 years, mainly on seismic data processing. She also worked for Kelman Technology Incorporation in Canada before joining CGGVeritas in 2003. Currently she is working in the marine processing department in the Calgary office of CGGVeritas. Li joined CREWES in January 2010 to work on her Master's degree. Her research interests are seismic imaging and seismic inversion.

Matt McDonald
M.Sc. Student
(Supervisor: Michael Lamoureux)

Matt McDonald is from Grand Forks, British Columbia, but has lived in Calgary for several years now. He holds an honours degree in Applied Mathematics from the University of Calgary and is currently pursuing a M.Sc. in Applied Mathematics with CREWES under the supervision of Dr. Michael Lamoureux. His current research is involved in the parallel implementation of numerical methods for solving hyperbolic systems of equations (such as those modeling acoustic and seismic waves) and comparison of the speed and accuracy of these methods. He spends his spare time fly-fishing and golfing in the summers, and ski-touring in the winters.

Liliana Zuleta
M.Sc. Student
(Supervisor: Don Lawton)

Liliana graduated from the Universidad Nacional of Colombia with a B.Sc. in Petroleum Engineering (1994). She worked for many years in seismic data acquisition and processing (mostly land) in many different countries around the world. She has a degree in "Safety and Environmental concerns in Mining" from l' Ecole des Mines d'Ales, France, and received a "Graduate Diploma in Geophysics" at Curtin University in Australia. In 2008. Her interest is in seismic data processing and reservoir characterization. Liliana joined CREWES in January 2010.

Recent Theses:

Hammad, Hussain (M.Sc.)
Waveform inversion for areas with complex near surface

Zhang, John Jianlin (Ph.D.)
Improving Reservoir Simulation with Time-lapse Seismic Surveys

Cooper, Joanna (M.Sc.)
Seismic acquisition footprint: modelling and mitigation

Full copies of student theses can be found at our website: www.crewes.org

Meet the New CREWES Staff

Dr. Mostafa Naghizadeh
Post Doctoral Researcher

Mostafa Naghizadeh received B.Sc. in Mining Engineering from the University of Kerman, Iran, in 2000 and M.Sc. in Geophysics from the University of Tehran, Iran, in 2003. He received his Ph.D. in Geophysics from the University of Alberta in 2009. His interests are in seismic data reconstruction methods, sampling theory and seismic imaging. He is currently a postdoctoral fellow with CREWES at the University of Calgary. Mostafa is the recipient of an Honorable Mention for Best Student Paper at the CSEG 2006 convention, CSEG Best Student Paper Award in 2007 and 2009, and best SEG Student Poster Award in 2008.

CREWES Sponsor's Meeting December 1—3, 2010

The 22nd Annual CREWES Sponsor's Meeting will be held in Banff, Alberta this year from December 1—3rd. The venue is the beautiful Banff Park Lodge (www.banffparklodge.com). Historically, every sponsoring company has sent from one to nine delegates to the meeting to attend the two days of technical sessions and participate in the social events, for some great networking opportunities. The meeting gives sponsoring delegates the opportunity to interact with graduate students and learn of the cutting edge research being performed by CREWES at the University of Calgary.

Rooms have been reserved for 100 attendees; however these rooms are only being held until **November 1st** before they are released back to the general public. If you are planning on attending the meeting this year, please book your room early!

Attendees can call 800-661-9266 and mention the CREWES conference, December 1 – 3, 2010 or Booking ID 12461 to make a guest room reservation at the preferred rate. You may also make a reservation by going to www.banffparklodge.com and selecting Conferences & Events and then Make a Conference Reservation:

Enter Group ID : **12461** Password : **449** and Find Group, then follow the booking procedure

Please note that rates are also valid 2 days pre & post the conference room block days of December 1 & 2 but anyone wishing to arrive before these dates or stay after must call the hotel's 800 number.

Please check our website in the coming months for updates and additional information.

We look forward to seeing all of you in December and renewing our old acquaintances and hopefully making new friendships as well.

Director Profile—Rob Ferguson

Rob Ferguson has been with CREWES since 2007. His research specialization is in reflection seismology applications of seismic imaging and modelling. Below, he groups his work in imaging and modelling into four main areas, and his students are indicated in parenthesis:

Regularization and datuming of seismic data (Marcus Wilson, Akshay Gulati): Acquisition of seismic data occurs in a natural setting, so data are often acquired with irregular spacing between measurements, and strong terrain variations introduce strong variations in the recorded data. Both effects cause spurious seismic events that mask events of interest. Our solution solves both problems simultaneously by a numerical inversion. Our approach is groundbreaking in that I replaced an expensive matrix-matrix multiplication by a new, truncated series expansion.

Seismic imaging in heterogeneous anisotropic media (Diane Lespinasse, Mahdi Al Mutlaq): In part of this work, we have generalized mathematically a large class of conventional imaging methods for seismic data to enable the hybridization of seismic imaging. The resulting hybrid *plans* the execution of imaging so that the best aspects of the numerous methods are combined. Interpretation and integration of geologic information and seismic data are an extension of this project.

Estimating the elastic parameters of heterogeneous anisotropic media by joint P- and S-wave inversion (Roohollah Askari): Seismic analysis space exists simultaneously in time and depth, rather than independently-in-depth or independently-in-time as is assumed conventionally. We use this multi-dimensional space to combine P- and S-wave recordings in a joint inversion scheme by which anisotropy parameters plus layer thicknesses are resolved.

Seismic modelling in heterogeneous anisotropic media (Vanja Milicevic, Ritesh Sharma): Wherever shales are present, anisotropy exists in the subsurface, and this causes image distortions that can be severe. In our work in anisotropic imaging, we have successfully developed ray-based approaches and phase-shift approaches that combine high accuracy with high-efficiency. A seismic imaging algorithm based on a traveltime (ray) approach is now in production at a seismic contractor. Computationally, we have access to a large cluster computer for 3D synthetic data, and 3D timelapse synthetic data.

Recent CREWES Conference Presentations

GeoCanada2010, May 2010 Calgary, Alberta

CREWES GeoCanada 2010 Posters

Date	Time	Location	Title	Authors
Seismic Interpretation and Case Studies Posters				
Monday May 10	Morning session	Poster Exhibition Floor	2D Seismic Modeling of the Redwater Leduc Reef, Alberta	Taher Sodagar*, Don Lawton
Signal Processing & Algorithms Posters				
Monday May 10	Morning session	Poster Exhibition Floor	Sensitivity Analysis of Receiver Clock-times when Locating Microseismic Events	John Bancroft
Monday May 10	Morning session	Poster Exhibition Floor	Time Picking on Noisy Microseismograms	Lejia Han*, Joe Wong
Monday May 10	Morning session	Poster Exhibition Floor	The Influence of Reflectivity Color on Gabor Deconvolution	Peng Cheng*, Gary Margrave
Monday May 10	Morning session	Poster Exhibition Floor	Overcoming Computational Cost Problems of Reverse-Time Migration	Zaiming Jiang*, Kayla Bonham, John Bancroft, Laurence Lines
Monday May 10	Morning session	Poster Exhibition Floor	Feasibility of Using Multigrid Methods for Solving Least-Squares Prestack Kirchhoff Migration Equation	Abdolnaser Yousefzadeh*, John C. Bancroft
Monday May 10	Morning session	Poster Exhibition Floor	Split-Step Two-Way Phase-Shift Time Stepping for Wavefield Propagation	Ben Wards
Monday May 10	Morning session	Poster Exhibition Floor	NFFT: Algorithm for Irregular Sampling	Akshay Gulati*, Robert J. Ferguson
Stress, Strain, Anisotropy and Natural Fractures Posters				
Monday May 10	Morning session	Poster Exhibition Floor	Spectral and Near-Field Characteristics of Induced Microseismicity	David Eaton*, Farshid Forouhideh, Mirko van der Baan
Subsurface Imaging & Structure Posters				
Monday May 10	Morning session	Poster Exhibition Floor	A Scattering Diagram Derivation of the Eikonal Approximation	Kris Innanen
Monday May 10	Morning session	Poster Exhibition Floor	Crustal Anisotropy of Hudson Bay from Ambient-Noise Tomography	Aganieszka Pawlak*, David Eaton
Monday May 10	Morning session	Poster Exhibition Floor	Numerical Fluid Flow Modelling and Its Seismic Response in Time-Lapse	Vanja Milicevic*, Robert Ferguson
Monday May 10	Morning session	Poster Exhibition Floor	Elastic Prestack Reverse-time Migration using a Staggered-grid Finite-Difference Method	Zaiming Jiang*, John Bancroft, Laurence Lines, Kevin Hall
Monday May 10	Morning session	Poster Exhibition Floor	3D R & T Coefficients for a Dipping Interface: A Plain Wave Domain Approach	Ritesh Kumar Sharma*, Robert J. Ferguson
Monday May 10	Morning session	Poster Exhibition Floor	The Volume Couple as a Source for Micro-Seismic Events	Peter Manning
Monday May 10	Morning session	Poster Exhibition Floor	Estimating the Sensitivity and Improving the Accuracy of the Velocity when Locating a Microseismic Event	John Bancroft
Characterization, Operations and Production of Shale Gas Posters				
Monday May 10	Afternoon session	Poster Exhibition Hall	Hypocenter Location via Hodogram Analysis of Noisy 3C Microseismograms	Joe Wong
Heavy Oil: Subsurface Poster				
Monday May 10	Afternoon session	Poster Exhibition Hall	Q and the Quest for Heavy Oil Viscosity	Fereidoon Vasheghani*, Larry Lines, Joan Embleton

April 19 & 20, 2010: 3D & Down Hole Seismic Survey at Priddis, Alberta

Recent CREWES Conference Presentations

CREWES GeoCanada 2010 Talks

Date	Time	Location	Title	Authors
Signal Processing & Algorithms				
Monday May 10	9:00	Palomino B/C	Q-Estimation from Uncorrelated Vibroseis VSP Model Data	Armin Haase
Monday May 10	9:20	Palomino B/C	Correcting PS Receiver Statics using Hybrid Raypath Interferometry	David Henley
Monday May 10	10:40	Palomino B/C	Nonstationary Predictive Deconvolution	Gary Margrave*, Michael Lamoureux
Signal Processing & Algorithms				
Monday May 10	1:10	Palomino B/C	Variable-Factor S-transform for Time-Frequency Decomposition, Deconvolution, and Noise Attenuation	Todor Todorov*, Gary Margrave
Monday May 10	1:30	Palomino B/C	Estimation of Q-factor and Phase Velocity using the Recovered stress-Strain Relaxation Spectrum	Dali, Zhang*, Michael Lamoureux, Gary Margrave
Monday May 10	1:50	Palomino B/C	Generalized Frames for Gabor Operators in Seismic Imaging	Michael Lamoureux*, Gary Margrave, Peter Gibson
Monday May 10	2:10	Palomino B/C	Interpolation of Aliased Seismic Data in the Curvelet Domain	Mostafa Naghizadeh*, Mauricio Sacchi
Monday May 10	4:10	Palomino B/C	Trace Interpolation and Elevation Statics by Conjugate Gradients	Marcus Wilson*, Robert Ferguson
Paleoproterozoic Tectonic Assembly of the W. Canadian Shield: New Findings & Implications for Paleocontinental Reconstruction				
Monday May 10	3:30	Palomino E	Geophysical Studies of the Deep Lithosphere beneath Hudson Bay and Environs: Implications for Paleoproterozoic Assembly of Laurentia	David Eaton*, Meghan Miller, Fiona Darbyshire
Advances in Seismic Acquisition				
Tuesday May 11	10:40	Palomino B/C	Comparison of Low-Frequency Data from Co-Located Receivers using Frequency Dependent Least Squares Subtraction Scalars	Kevin Hall*, Gary Margrave, Malcolm Bertram
Stress, Strain, Anisotropy and Induced Fractures				
Tuesday May 11	11:00	Palomino D	Are Double-Couples Over-Represented in Microseismic Focal Mechanism Studies?	Farshid Forouhideh*, David Eaton
Stress, Strain, Anisotropy and Natural Fractures				
Tuesday May 11	3:10	Palomino D	Interpretation of Natural Fractures from the Traveltime Variation with Source-Receiver Azimuth in the Alberta Foothills	Draga Talinga*, Don Lawton
Tuesday May 11	3:50	Palomino D	Numerical Modeling of Shear-Wave Splitting and Azimuthal Velocity Analysis in Fractured Media	Zimin Zhang*, Don C. Lawton, Robert R. Stewart
Subsurface Imaging & Structure				
Wednesday May 12	1:10	Palomino B/C	Structure of Earth's Shallow Outer Core: No Evidence for Stratification	Catherine Alexandrakis*, David Eaton
Heavy Oil - Subsurface				
Wednesday May 12	1:50	Boyce Theatre	Effect of Heavy Oil Rock Texture on VP/VS Ratios Derived from Logs	Carmen C. Dumitrescu*, Larry Lines

EAGE 72nd Conference, Barcelona, Spain June 2010

Gabor domain analysis of Q in the nearsurface: Ferguson, R.J, Margrave, G. F, and Hall, K.W.

Full and current listings of all conference presentations can be found on our website:

www.crewes.org

Left: Malcolm Bertram preparing down hole equipment at Priddis, Alberta on April 19, 2010. **Right:** Malcolm Bertram and Rolf Maier preparing the down hole equipment on April 19, 2010 at Priddis, Alberta.

Microseismic Hypocenter Location Using Non-linear Optimization

Introduction

In locating hypocenters of microseisms caused by hydraulic fracturing, we use observed arrival azimuths and times at 3C geophones with known coordinates. From these data, we must determine the microseism source coordinates (x_s, y_s, z_s) and hence the point of fracturing. For the present analysis, we generated synthetic data for a layered-earth velocity model and an array of downhole 3C geophones in a vertical observation well, with a microseismic source located some distance away, as shown on the left panel of Figure 1.

Ray tracing through the velocity model produces calculated arrival times from the source location. The right side of Figure 1 shows that the arrival-time curve is non-hyperbolic.

Unknown parameters in the survey setting can be found by minimizing the misfit between observed and calculated arrival times using non-linear optimization schemes (generally called inversion techniques by geophysicists). Optimization techniques fall in two categories: *direct-search*, and *gradient-based*. Examples of direct search techniques are the pattern search method and the genetics algorithm. Example of gradient-based techniques are the Levenberg-Marquardt algorithm and the conjugate-gradient method. These algorithms are available in the MATLAB Optimization Toolbox, and are quite easy to use.

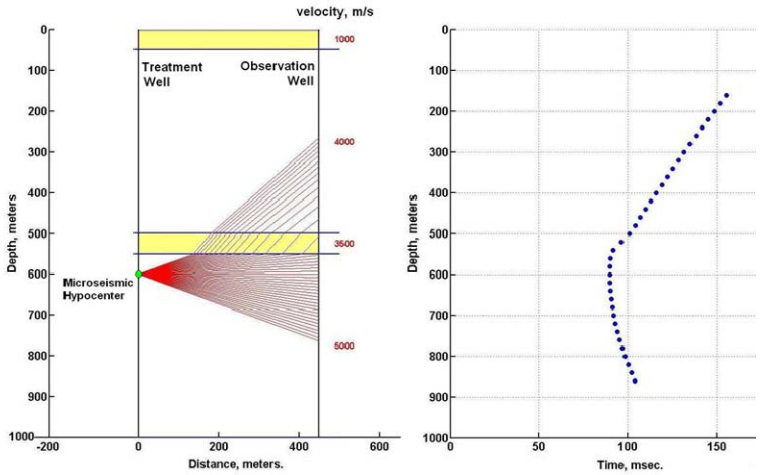


FIG. 1: Left: ray-tracing to obtain first arrival times between a microseismic source and an array of geophones in a vertical borehole. Note the refraction through the low-velocity zone. Right: the associated arrival times.

Calibrating Velocities with a Genetic Algorithm

In the analysis of a real-world microseismic dataset, an essential first step is to calibrate the velocity model. For our current study, we generated "observed" direct arrival times for the velocity model of Figure 1 from a simulated casing perforation shot in the treatment well. We know the observed arrival times, the geophone coordinates, and the source coordinates. We assume we know (from gamma-ray logs) the depths of the layer boundaries, and we must find the velocity values. We calculated ray-traced arrival times for different velocity values. We defined an objective function equal to the root-mean-squared misfit between the calculated and observed times.

We selected the GA option in the MATLAB *optimtool* utility to use a genetics algorithm (GA) to find a set of velocity values that minimizes the objective function. To accelerate the search, reasonable lower and upper bounds for the velocities [v_1, v_2, v_3, v_4] were set at [1000, 2000, 2000, 2000] and [1000, 6000, 6000, 6000] m/s. Since the overburden velocity played no role in determining arrival times for this particular source-receiver geometry, we fixed it by setting its lower and upper bounds at 1000m/s. After a number of iterations (or "generations"), the program returned velocity values that approached the global minimum within a user-determined small tolerance.

Figure 2 and Table 1 show the results of a specific run of the GA search. After 69 generations, during which there were 1380 evaluation of the objective function, the returned velocity values for the four layers were 1000, 3961, 3551, and 4997m/s. These were very close to the true velocity values. The minimum RMS time difference for 20 members of the last generation was .0414 ms, and the mean RMS time difference for the 20 members was .0440ms.

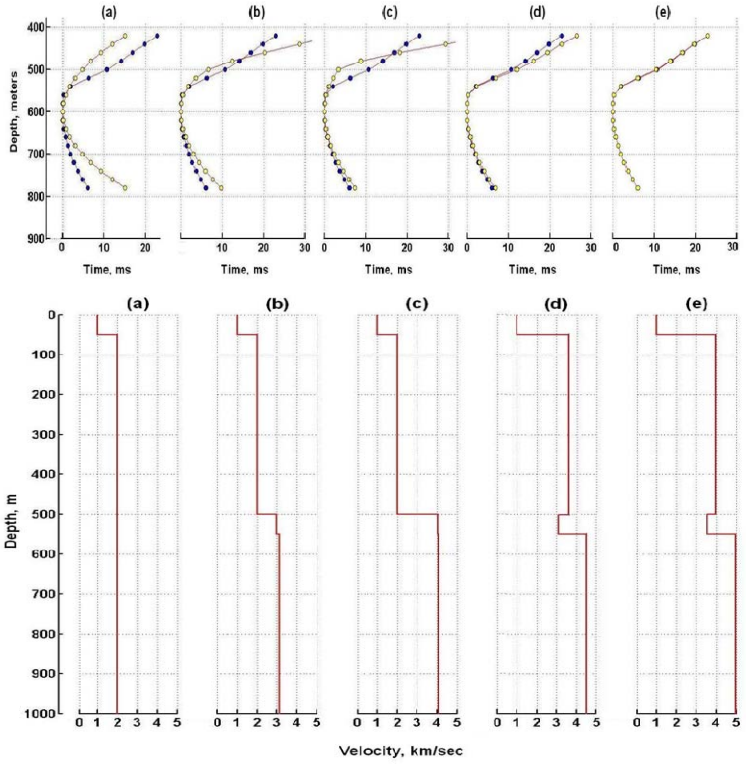


FIG 2: Calibration of layer velocities using GA optimization. Blue dots on the top panel are observed times from a casing perforation shot; yellow dots are the calculated times for the velocity profiles on the bottom panel. (a) Results for (a) an initial guess; (b) after 10 generations; (c) after 20 generations; (d) after 40 generations; (e) after 69 generations, a good fit is found.

Table 3. Calibrating model velocities (m/s) using GA.

Generation	v_1	v_2	v_3	v_4	RMS error (ms)
Initial guess	1000	2000	2000	2000	31.8
10	1000	2005	3001	3116	29.43
20	1000	2000	4029	4087	11.03
30	1000	3480	3133	4472	9.14
69	1000	3961	3551	4997	.0414
True values	1000	4000	3500	5000	0

Hypocenter Location

We now address the problem of finding the unknown coordinates of the source location of a microseismic event., knowing the arrival times at several geophones. For the single borehole in the cylindrically symmetric geometry of Figure 1, arrival times yield only the cylindrical coordinates (r_s, z_s) where r_s is the radial distance from the observation well. In order to get the coordinates (x_s, y_s), we must use three component geophones, and determine azimuth angles from the x- and y-components using with hodogram analysis. Combining the azimuths with r_s then gives estimates for (x_s, y_s). Details for hodogram/azimuth analysis can be found in Han et al. (CREWES Report 13, 2009). Here, we limit the discussion to finding (r_s, z_s) via inversion of arrival times for a layered-earth velocity structure.

Inverting Reduced Arrival Times

We produced a set of "observed" microseismic arrival times by ray-tracing from a hypocenter located at (x_s, y_s, z_s) = (0, 0, 600m) for 36 geophones in the vertical observation well located at r=520m shown on Figure 1.

In a real microseismic survey, the actual time of occurrence t_0 of a microseismic event is unknown. It would be an extra parameter that must be found if true first-arrival times were used in the inversion scheme. Instead, we can use the reduced arrival times $t_{obs}(i) - min(t_{obs}(i))$ and $t_{cal}(i) - min(t_{cal}(i))$ as the input data to the algorithm. This simple adjustment means that arrival-time moveouts rather than absolute arrival times are the basis for locating the hypocenter, eliminating the need to know the event time t_0. The moveouts must be large enough so that they exceed any time-picking errors. They will contain sufficient geometric information for locating the hypocenter if the angular aperture subtended by the geophone array relative to the source is 20 degrees or more.

We know the reduced observed arrival times, the geophone coordinates, and the velocity model. Therefore, we can estimate the hypocenter coordinates using nonlinear optimization to find a set of values for (r_s, z_s) that minimizes an objective function equal to the root-mean-squared (RMS) misfit between the ray-traced arrival times and the observed arrival times. For this, we applied a gradient-based technique, a modified Levenberg-Marquardt (LM) algorithm.

LM is prone to be trapped in local minima, and it converges very slowly where the objective function has near-zero gradients (e.g., data valleys and saddle points). Its performance is also dependent on the initial guess for values of the parameters to be found. The closer the starting values for the parameters are to the true values, the faster and the more likely will be the convergence to the true values.

Figure 3 shows that it took 200 iterations of the LM algorithm to reduce the root-mean-squared misfit time to less than .2ms. At each iteration, numerically constructing the partial derivatives required by the LM algorithm and finding optimum step sizes for correcting the hypocenter coordinates involved many forward calculations.

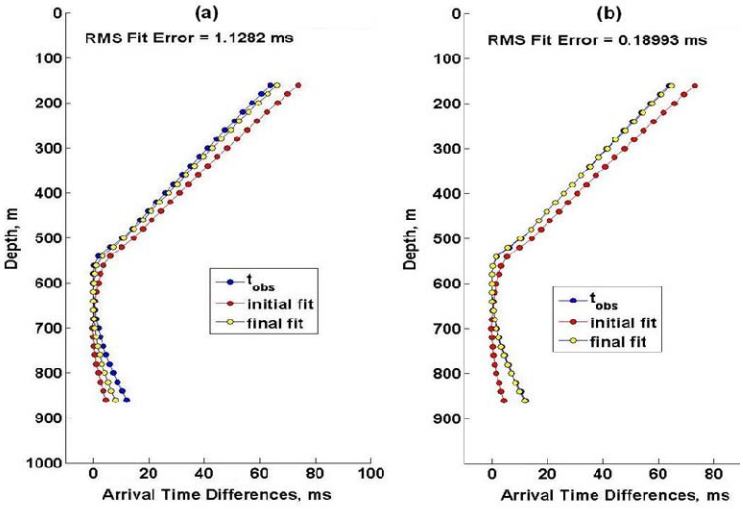


Fig. 3: Reduced arrival times after (a) 30, and (b) 200 iterations of the modified LM optimization routine. The RMS misfit between observed times and calculated times after 200 iterations is about 0.19ms.

Table 2. Summary of the modified LM inversion results for Figure 3.

Iteration	r_s , m	x_s , m	z_s , m	RMS fit error
Initial guess	540	-20	700	3.14 ms
30	581	-61	640	1.13 ms
200	513	6.5	606	0.19 ms
True values	520	0	600	0

Conclusions

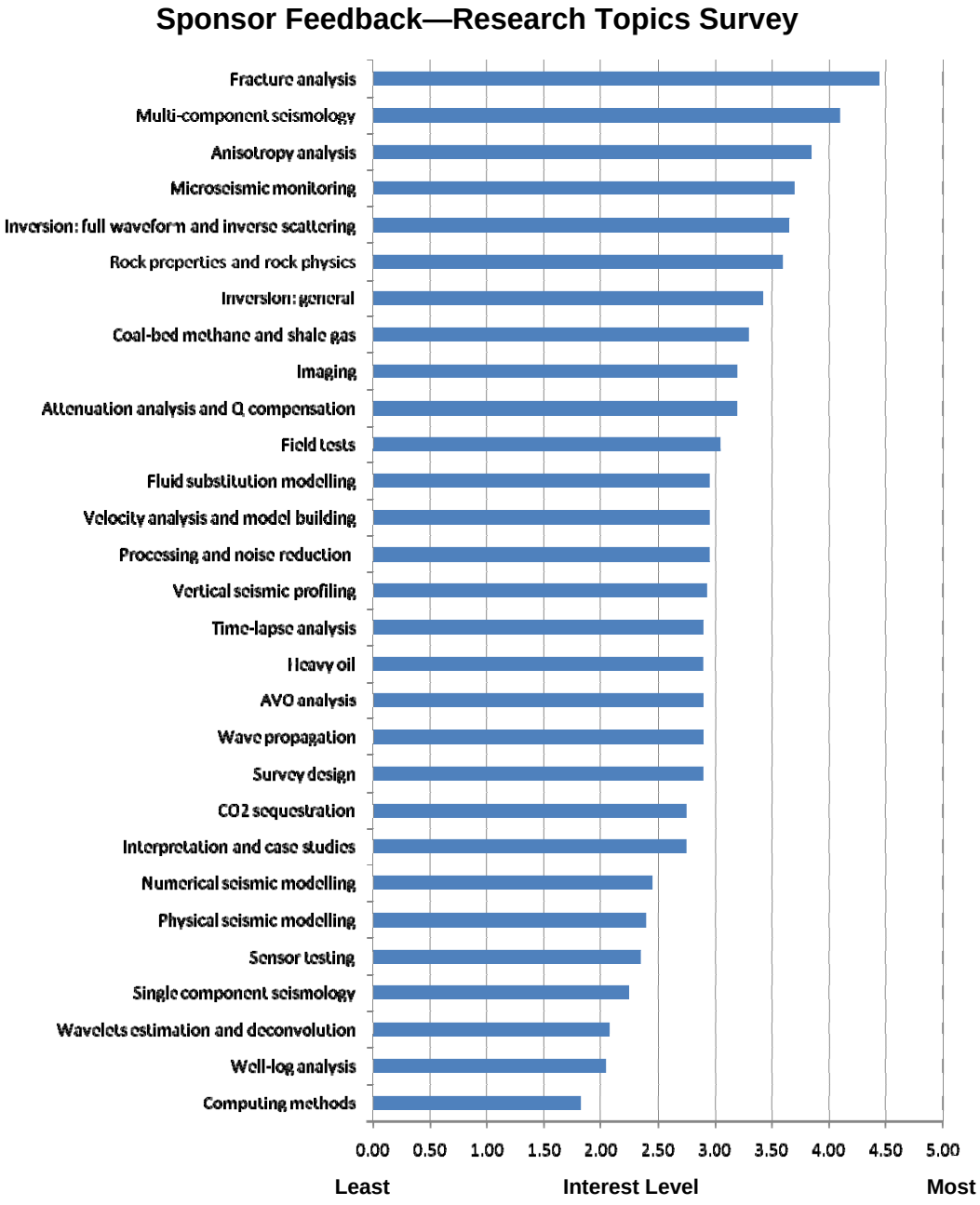
Inversion of first-arrival times for locating microseismic hypocenters is not effective unless the angles subtended by both surface and well-located geophone arrays (relative to the microseismic source) are large enough to yield significant arrival-time moveout. In this study, we found that a direct search algorithm such GA was more suitable for inverting microseismic arrival time data than a gradient-based method such LM. GA was less prone to be caught in local minima or long data valleys. Moreover, unlike the gradient-based LM algorithm, the GA direct search method did not require that partial derivatives for the objective function be calculated, and so was faster.

Submitted by Joe Wong, Research Geophysicist

21st Annual Sponsor's Meeting

CREWES 21st Annual Sponsors Meeting (2009)

The 21st Annual Sponsor's meeting was held in Canmore Alberta from November 18—20, 2009. There were 50 from 23 sponsoring companies gathered with faculty, staff and students of the CREWES project to hear presentations spotlighting the most recent research being done by CREWES. Our abstract book took on a new look with coloured diagrams on every page.



Find us on the web at www.crewes.org

A list of our Sponsors

We would like to acknowledge and thank our 2010 sponsors:

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CREWES— who's who?

Contact Note: *Readers wishing to contact staff and students should add the domain @ucalgary.ca to the usernames listed below*

Leadership:
Dr. John Bancroft, Adjunct Faculty: bancroft
Dr. Dave Eaton, Associate Director: eaton
Dr. Robert Ferguson, Associate Director: ferguson
Dr. Kris Innanen, Associate Director: k.innanen
Dr. Michael Lamoureux, Adjunct Faculty: mikel@math
Dr. Don Lawton, Associate Director: lawton
Dr. Larry Lines. Associate Director: lrlines
Dr. Gary Margrave, Director: margrave
Dr. Robert Stewart, Associate Director: stewart

Management and Professional Staff:
Laura Baird: labaird
Malcolm Bertram: bertram
Kevin Hall: kwhall

Research Staff:
Kevin Bertram: klbertra
Dr. Pat Daley: pdaley
Eric Gallant: egallant
Dr. Arnim Haase: haaseab
Dave Henley: dhenley
Han-Xing Lu: hxlu
Dr. Rolf Maier: maier
Dr. Mostafa Naghizadeh: mnaghiza
Dr. Joe Wong: wongjoe
Dr. Peter Manning: pmmannin

Active Graduate Students:
Abdullah A. Shuhail: shuhail
Mahdi Al Mutlaq: mhalmutl
Abdallah Al-Zaharani: aaalzahr
Roohollah Askari: raskari
Christopher Bird: cwbird
Peng Cheng: chengp
Joanna Cooper: jkcooper
Farshid Forouhideh: fforouhi
Thais Guirigay: taguirig
Akshay Gulati: agulati
Lejia Han: lehan
Zaiming Jiang: jianz
Hassan Khaniani: khaniani
Diane Lespinasse: djlespin
Faranak Mahmoudian: fmahmoud
Matt McDonald: mamcdonal@msn.com
Vanja Milicevic: vmilicev
Lauren Ostridge: ostridge
Agnieszka Pawlak: aepawlak
Baolin Qiao: bqiao
Ritesh Kumar Sharma: rksharma
Taher Sodagar: tmysodag
Virginia Vera: vcvera
Ben Wards: bdwards
Marcus Wilson: wilsonmr
Abdolnaser Yousefzadeh: ayousefz
Zimin Zhang: zzhan
Lilian Zuleta: lmzuleta

CREWES Affiliated Students
Paul Anderson: pfanders
Joaquin Aristimuno: jaristim
David Cho: dcho@calgary.oilfield.slb.com
Jean Cui: xiaoqin.cui@cggveritas.com
Saul Guevara: seguevar
Chad Hogan: cmhogan
Li Lu: lilu
Carlos Montana: rcamonta
A.-Nassir Saeed: ansaeed
Todor Todorov: titodoro

U of C EAGE Student Chapter Place Second in Geo-Quiz

Congratulations go to the Department of Geoscience's EAGE student chapter members who placed second in the first ever EAGE (European Association of Geoscientists and Engineers) online Geo-Quiz on March 31, 2010. 15 of the 18 students in the EAGE student chapter are CREWES Grad Students.

The EAGE will provide three U of C student members (all CREWES students) with financial support to participate in the live Geo-Quiz in Barcelona, Spain in June.

Photos in the newsletter are courtesy of Laura Baird and Kevin Bertram

CREWES News

CREWES Project
Department of Geoscience
2500 University Drive NW
Calgary, Alberta T2N 1N4

Phone: 403-220-8863
Fax: 403-284-0074
E-mail: crewesinfo@crewes.org

CREWES *(The Consortium for Research in Elastic Wave Exploration Seismology) is a dynamic collaboration, of academic scientists, their industrial supporters and a large body of graduate students, conducting research in applied seismology. Research topics include acquisition, data processing, imaging, inversion, and interpretation. CREWES often records its own data, preferably with 3C receivers. Industry sponsors include companies from Canada and around the world*

We're on the web:
www.crewes.org

22nd Annual Sponsor's meeting will be held in Banff, Alberta from December 1—3, 2010. Check our website for details.

The CREWES Project Staff January 2010, University of Calgary

Back: Eric Gallant, Peter Manning, Dave Henley, Kevin Bertram, Arnim Haase, John Bancroft, Rolf Maier

Front: Han-Xing Lu, Malcolm Bertram, Laura Baird, Joe Wong, Mostafa Naghizadeh, Kevin Hall