CREWES

Consortium for Research in Elastic Wave Exploration Seismology

PROJECT OVERVIEW
2016

**UNIVERSITY OF
CALGARY**

RESEARCH AGREEMENT

This Agreement is made as of the ==1st day of January,== 2016.

between

-insert sponsor details-
Address
("Sponsor")

- and -

THE GOVERNORS OF THE UNIVERSITY OF CALGARY
2500 University Drive NW
Calgary, Alberta, T2N 1N4 Canada
(the "University")

WHEREAS Sponsor wishes to make a research grant (the "Grant") to participate in the Consortium for Research in Elastic Wave Exploration Seismology (the "CREWES Project") under the direction and supervision of Dr. Gary Margrave (the "Project Leader"); and

WHEREAS the University is willing to accept and administer the Grant on behalf of the Project Leader and make its premises, facilities, and services available for the CREWES Project, all to the extent set forth herein;

NOW THEREFORE THIS AGREEMENT WITNESSETH THAT FOR GOOD AND VALUABLE CONSIDERATION, SPONSOR AND THE UNIVERSITY AGREE AS FOLLOWS:

1.   SCOPE OF RESEARCH

1.1   The Project Leader shall carry out the CREWES Project in accordance with the Statement of Work contained in Schedule 'A' and Budget contained in Schedule 'B'.

1.2   The CREWES Project shall be conducted in accordance with applicable policies and priorities of the University.

2.   PROJECT LEADER

2.1   The CREWES Project shall be carried out under the direction and supervision of the Project

Leader who shall have responsibility for the scientific and technical conduct of the work. If for any reason Dr. Gary Margrave is unable to complete the CREWES Project as Project Leader and a successor acceptable to both Sponsor and the University is unavailable, this Agreement shall terminate.

3.   **TERM**

3.1   This Agreement shall be effective from January 1, 2016 to December 31, 2021 (the "Term"), provided that Sponsor may terminate this Agreement prior to the end of any year of the Term as follows:

(a)   For termination effective January 1, 2017, written notice must be delivered to University prior to December 1, 2016;

(b)   For termination effective January 1, 2018, written notice must be delivered to University prior to December 1, 2017;

(c)   For termination effective January 1, 2019, written notice must be delivered to University prior to December 1, 2018;

(d)   For termination effective January 1, 2020, written notice must be delivered to University prior to December 1, 2019;

(e)   For termination effective January 1, 2021, written notices must be delivered to University prior to December 1, 2020.

3.2   The University may terminate this Agreement at any time with written notice to Sponsor, to be delivered sixty (60) days prior to the intended date of termination.

4.   **PAYMENT AND ACCOUNTS**

4.1   Subject always to the provisions of paragraph 3 above, Sponsor shall pay to the University the sum of $49,000.00 (the "Sponsor Fee") for each year of the Term within thirty (30) days of receipt of an invoice from the University. The Sponsor shall pay to the University the full amount of the Sponsor Fee regardless of any withholding taxes applicable in the jurisdiction of the Sponsor.

5.   **REPORTS**

5.1   The University shall provide Sponsor with an annual research report of the CREWES Project at the time and in the manner outlined in the Statement of Work.

5.2   The University shall also provide Sponsor with an annual financial report itemizing revenue

and expenditures for the CREWES Project during each of the Term.

6. ANNUAL SPONSOR MEETING

6.1   The University will conduct an annual CREWES Project meeting throughout the Term (the "Annual Sponsor Meeting") exclusively for sponsors to provide sponsors with the first opportunity to review research results generated each year and prior to any publication. The Sponsor will have the right to attend this meeting during the continuance of this Agreement provided that all Sponsor Fees are fully paid up for the current year.

7. RESEARCH RESULTS AND PUBLICATION

7.1   All all data and information created in the performance of the CREWES Project including, but not limited to, substances, processes, formulations, technical information, data, reports, photographs, drawings, plans, specifications, models, prototypes, inventions, patterns, samples, software, designs, computer programs, databases or know-how, whether or not protected by patent, copyright, industrial design (Research Results") shall be owned by the University in accordance with the policies of the University.

7.2   The University shall have the right to publish or otherwise disseminate Research Results in accordance with the policies of the University, and at the discretion of the Project Leader, provided however that no publication may occur prior to the presentation of Research Results at the Annual Sponsor Meeting. The University will submit to the Sponsor a copy of the proposed publication resulting from the CREWES Project prior to submission for publication. In the event that Sponsor determines that Research Results contain Sponsor Confidential Information, Sponsor shall notify University in writing within thirty (30) days following receipt of the proposed publication and University shall remove Sponsor Confidential Information prior to publication. In no event shall a proposed publication be delayed more than thirty (30) days from the date of receipt by the Sponsor. If a Sponsor does not provide notice of Confidential Information within the thirty (30) day period, Sponsor will be deemed to have consented to publication of the Research Results. Notwithstanding the above, in no event shall publication be postponed such that a graduate student thesis defense is delayed.

8. LICENSE TO USE DATA AND SOFTWARE

8.1   Upon and subject to the terms and conditions set forth in this paragraph 9, Sponsor shall have access to:

(a)   physical modelling facility data and field data acquired by the CREWES Project which may be released by the University during the Term of this Agreement (collectively the "Data"); and

(b)   such computer software to assist in analyzing the Data as may be developed by the

University in respect of the CREWES Project and released by the University during the Term of this Agreement (the "Software");

provided however, that Sponsor shall be responsible for reproduction and mailing costs of the foregoing.

8.2   The University grants to Sponsor a non-transferable and non-exclusive right and license to use the Data for its internal purposes, and to show the Data to such third parties as Sponsor may desire; provided however, that Sponsor shall not, at any time, sell, transfer, convey, license, sublicense or otherwise dispose of the Data or any interest therein at any time to any third party.

8.3   The University also hereby grants to Sponsor a non-transferable and non-exclusive right and license to use the Software (other than any proprietary software provided to the University by third parties) for its internal purposes; provided however, that Sponsor shall not, at any time, sell, transfer, convey, license, sublicense or otherwise dispose of the Software or any interest therein at any time to any third party. Notwithstanding the foregoing, if Sponsor, at any time, should materially modify the Software (other than any proprietary software provided to the University by third parties), then Sponsor shall be entitled to sell, transfer, assign, license, sublicense or otherwise dispose of such materially altered Software (other than proprietary software provided to the University by third parties) to any third party as Sponsor may desire.

8.4   Sponsor is responsible for maintenance of the Data and Software. Sponsor acknowledges and agrees that the Data and Software will be provided to Sponsor "as is" and that the University neither makes nor gives any representation, warranty or condition of any kind in respect of the Data or Software, express or implied, in fact or in law or those arising by statute or otherwise or from a course of dealing or usage of trade, including, without limitation, representations, warranties or conditions of merchantability, quality or fitness for a particular purpose. The University shall not be liable for any direct, indirect, consequential or any other losses or damages suffered or sustained by Sponsor or any third parties, whether based in contract or tort (including, without limitation, negligence) or otherwise, as a result of or in connection with use or application of the Data or Software, or any invention, technology or product produced using or incorporating the Data or Software, and Sponsor shall indemnify the University and save the University harmless of and from all actions, causes of action, damages, demands, claims, losses, liabilities, costs and expenses of every nature or kind whatsoever, which may be suffered, sustained, paid or incurred by the University as a result of, or in connection with, any claim in relation to the Data and/or Software made against the University by any third party who directly or indirectly acquired the Data and/or Software from Sponsor, whether authorized or not hereunder.

8.5   Sponsor shall be exclusively responsible for the supervision, management and control of its use of the Data and Software.

9.   CONFIDENTIAL INFORMATION

9.1   The University and Project Leader shall use reasonable efforts (and, in any event, efforts that are no less than those used to protect their own Confidential Information) to protect from disclosure such information that is the Confidential Information of Sponsor. Sponsor agrees that it shall use reasonable efforts (and, in any event, efforts that are no less than those used to protect its own Confidential Information) to protect from disclosure such information that is the Confidential Information of the University and Project Leader and other sponsors of the CREWES Project. For the purposes of this Agreement, the expression "Confidential Information" means only information which is clearly marked and identified as being confidential information of a party; provided however, that the expression "Confidential Information" shall not include any information which:

(a)   is or becomes publicly available through no fault of the other party or parties;

(b)   is already in the rightful possession of the other party or parties prior to its receipt from the other party or parties;

(c)   is independently developed by the other party or parties;

(d)   is rightfully obtained by the other party or parties from a third party which has no obligation to keep the information confidential;

(e)   is disclosed with the written consent of the party whose information it is;

(f)   is published or otherwise disseminated under paragraph 6 above with the approval of Sponsor or as a consequence of the failure of Sponsor to object to the same within the time limit set forth in paragraph 6 above; or

(g)   is disclosed pursuant to court order or other legal compulsion.

9.2   The aforesaid obligation not to disclose Confidential Information shall survive termination of this Agreement for a period of two (2) years, and thereafter there shall be no obligation to keep such Confidential Information confidential.

10.   LIABILITY

10.1   Sponsor agrees to hold harmless, indemnify and defend the University (and its successors, assigns, officers, directors employees and students) from all liabilities, demands, damages, expenses and losses arising out of the use by Sponsor or by any party acting on behalf of or under authorization from Sponsor of the Data or Software or out of any use, sale or other disposition by Sponsor, or by any party acting on behalf of or under authorization from Sponsor, of products made by use of the Data or Software.

10.2   University agrees to hold harmless, indemnify and defend the Sponsor (and its successors,

assigns, officers, directors and employees) from all liabilities, demands, damages, expenses and losses arising out of the use by University or by any party acting on behalf of or under authorization from University of the Data or Software or out of any use, sale or other disposition by University, or by any party acting on behalf of or under authorization from University, of products made by use of the Data or Software.

10.3   To the extent permitted by law, each party agrees to defend, indemnify and hold the other party (and their respective successors, assigns, officers, directors, employees and students) harmless from and against any and all claims or causes of action arising from the CREWES Project which relate to: a) for loss of damage to their respective property and equipment and b) from and against any and all claims or causes of action for injury to or death of their respective employees, and regardless of the sole, joint or concurrent negligence of the other. However, the indemnification contained in this paragraph shall not apply to any claim or liability to the extent that such claim or liability is attributable to the gross negligence or wilful misconduct of the indemnified party.

10.4   In no circumstances shall either party be liable to the other party for special, indirect, consequential or punitive damages resulting from or arising out of this Agreement or the CREWES Project including, without limitation, loss of use, loss of profit, or business interruptions, however the same may be caused and regardless of the another party's sole or concurrent negligence.

10.5   In no event shall the University be liable to the Sponsor, its officers, employees and agents for claim in either contract or tort arising out of this Agreement or the Project resulting in damages exceeding the amount paid by the Sponsor to the University pursuant to section 3 herein.

11.   FIELD WORK

11.1   The University and Sponsor acknowledge that the scope of the CREWES Project does include field work. Such field work would include surface seismic surveys, geological mapping and borehole experiments including well-logging and vertical seismic profiles. If any CREWES Sponsor wishes to engage CREWES in specific field work activities, under the direction of the Sponsor, a separate Agreement will be required between the University and the Sponsor, upon such terms and conditions as may be satisfactory to the University and the Sponsor.

12.   FREEDOM OF INFORMATION AND PROTECTION OF PRIVACY ACT

12.1   The Sponsor and the University acknowledge that this Agreement and the relationship between the Sponsor and the University will be subject to the provisions of The Freedom of Information and Protection of Privacy Act (Alberta).

13.   RELATIONSHIP OF PARTIES

13.1   The Project Leader and the University agree that they are acting independently and are not

employees of Sponsor. This Agreement does not constitute a partnership between the University and Sponsor.

14. ASSIGNMENT

14.1   Neither the University or Sponsor or the Project Leader may assign this Agreement without the prior written consent of the others.

15. GOVERNING LAW

15.1   This Agreement shall be governed by and shall be interpreted in accordance with the laws of the Province of Alberta and Sponsor hereby expressly attorns to the jurisdiction of the courts of Alberta for enforcement thereof.

16. COUNTERPARTS

16.1   This Agreement may be executed in any number of counterparts, with the same effect as if all parties hereto had signed the same document. All counterparts shall be construed together and shall constitute one and the same original agreement. Delivery of this Agreement by facsimile transmission shall constitute valid and effective delivery.

IN WITNESS WHEREOF the parties have executed this Agreement on the date first written above.

Sponsor   **THE GOVERNORS OF THE UNIVERSITY OF CALGARY**

per:_____   per:_____

Name: Name:

Title: Title:

Date:_____   Date:_____

Schedule "A"
Research Summary and Statement of Work

Background

CREWES has conducted research in all aspects of multi-component exploration seismology since 1988. This is a very broad field in the sense that expertise from many different disciplines and technologies can be usefully brought to bear for imaging the subsurface. In this proposal, CREWES will carry out basic and applied research spanning the themes of acquisition and instrumentation, data processing and analysis, imaging, inversion, interpretation, simulation of acoustic and elastic seismic waves, and related ancillary fields like geophysical well logging and georadar (GPR).

To carry out this program in a meaningful way, CREWES will continue to: support a large, experienced technical staff, maintain and operate a wide array of field equipment, support a high capacity computation facility, and bring together a diverse team of highly skilled PIs (principal investigators).
As a significant additional component of the project, CREWES will continue to support a cadre of graduate students to work, under the supervision of the PIs, on a wide array of research projects that will mature into research reports, published papers, and theses aligned with the themes outlined above.

Research Direction

CREWES will determine research directions, guided by the need for ever better seismic images. The estimation of earth properties from seismic data is an extremely complex physics problem that stands as a "grand challenge" of science. This problem has been able to absorb the combined efforts of thousands of scientists from dozens of disciplines for decades and yet remains "unsolved". However, every incremental advance has great potential benefits to society.

Specific research topics will be chosen by the principal investigators, possibly in consultation with scientists from sponsoring companies. Most of the principal investigators have industry experience and all interact with industry on a high-priority basis. This mechanism ensures that those topics addressed in any particular year are either of current interest or have significant promise for potential benefits; as judged by the principal investigators.

In general, CREWES will seek to improve seismic images through better field techniques and improved instrumentation for recording multi-component seismic data, more sophisticated data processing algorithms, better understanding of the underlying physics, improved computational methods, more sophisticated mathematics, and incorporation of ancillary knowledge such as well logs and rock properties

Research outcomes and products

Research activity within CREWES will continue to generate a number of valuable products. These include an annual research report which typically contains near 100 research papers, research software, and seismic data acquired in field experiments or produced through numerical and physical modeling.

These products will continue to be delivered to sponsors on an annual basis. In addition, CREWES will continue to produce, as one of its key deliverables, a steady stream of highly trained graduate students who are able to enter industrial jobs and become immediately productive.

Schedule "B"
Budget
(as of May 2015)

Year	2014	Estimate 2015
balance forward	1,123,349	
Revenue	1,451,057	1,363,500
Expenditures		
Salaries and Benefits (9-11 individuals)	651,512	754,000
Student Salaries (20-25 individuals)	459,154	400,000
Investigator Salary Top Up (3-5 individuals)	129,600	110,400
Equipment, Office and Lab	54,134	35,000
Materials and Supplies	32,159	11,000
Office Supplies	5,852	6,000
Expend. Equipment/Software	14,753	25,000
Vehicle Expense	240	500
Books, Reprints		
Deliveries/Shipping/Telecom/shipping	4,641	5,000
Copying, Other Services	3,348	7,000
Travel and Conventions	45,789	45,000
Meeting Expenses	60,373	35,000
Field Surveys, Processing	36,603	
Tuition Fees, Training	930	2,000
Memberships and Dues	1,029	1,000
Technology Field Trials and Equipment	-2,113	25,000
Overhead (paid to University of Calgary)	118,499	186,200
Total	1,616,503	1,648,100
Annual Balance	-165,446	-284,600
Combined Balance	957,903	673,303

CREWES Data Sets

CREWES sponsors have access to our collection of multi-component datasets for the cost of duplication.

Seismic Data Available:

- Blackfoot 1995 and 1997: 3C-2D (low frequency), 3C-3D and VSP

- Jumping Pound 3C-2D using MEMS-based geophones (I/O Vectorseis®)

- Ultrasonic physical model data: 2D and 3D

- Castle Mountain 3C-2D (crooked line) using digital geophones (I/O Vectorseis®)

- Alder Flats 3C-2D 2007

- Priddis surveys: 1C-2D and 1C-3D vibrator source surveys, 3C-2D hammer seismic surface lines, and a borehole hammer seismic survey and accompanying well logs. This data was acquired during the annual geophysics field school and various research programs. Also available are VSP and land streamer data.

- Spring Coulee: 6.5 km 3C-2D survey in Southern Alberta; Dynamite and vibrator sources at 30 m source spacing recorded by analog (SM-7, SM-24) and digital 3C geophones (DSU 3). Receiver spacing was 10 m. 3C VSP data are also available.

- Hussar Low Frequency 2011. 3C-2D multi-sensor, multi-source experiment intended to generate and record low frequency seismic data.

Software Distributed to CREWES Sponsors

Seismic Processing Modules

- **3drvspbin:** bins 3-D RVSP data and maps it into the common reflection point domain. [p]
- **Array form:** tests the effect of different kinds of receiver arrays based on non-arrayed, high-resolution data.
- **bicorr:** Cross bicorrelation function [p]
- **CCPStack:** depth-variant converted-wave binning/stacking. [p]
- **CCP3DStack:** depth-variant converted-wave binning/stacking. [p]
- **clipper:** non-linear spectral clipping to attenuate strong monochromatic noise. [p]
- **cspgather & cspfilter:** implements the common scattering point gather prestack time migration. It includes 3-D processing and laterally varying velocity field. The filter module allows for anti-alias, and tapered dip filter correction. [p]
- **CSP Statics:** calculate residual statics.
- **foci:** Pre- and Post-stack depth migration using explicit wavefield extrapolation in the space-frequency domain. [m]
- **forfoci:** Pre- and Post-stack depth migration using explicit wavefield extrapolation in the space-frequency domain.
- **frmath:** Frequency domain panel process toolbox program. [p]
- **gabor**: Gabor deconvolution: a time-varying deconvolution whose operator adapts to the characteristics of the data. [p]

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[*] Some packages require third-party software environments: [p] – ProMAX, [m] – Matlab, [w] – Microsoft Windows

- ▪ **gabor2**: Gabor deconvolution using a Lamoureux window functions instead of time-shifted Gaussian windows.
- ▪ **gabor_sc**: Surface-consistent, iterative Gabor deconvolution: also has diagnostic mode to output Gabor spectra for display [p]
- ▪ **latpsinv:** estimates S-wave velocity from P-S seismic data by constrained inversion. [p]
- ▪ **meanoff:** data preparation for PP-PS inversion; calculates the mean source-receiver offset for ensembles of input traces and sets trace headers. [p]

- **Nonstationary Deconvolution:** corrects seismic data for source signature and anelastic attenuation. [m]
- **Nonstationary phase-shift migrations:** Isotropic phase shift migrations based on Fourier domain nonstationary phase shift. The post stack migration code comes in three forms corresponding to two nonstationary formulations: phase shift plus interpolation and nonstationary phase shift. This package includes a TI migration for source gathers. [m]
- **PPPSAvostack:** Simultaneous PP and PS Inversion [p]
- **radtran:** Radial trace transform [p]
- **radfilt:** Coherent noise filtering using the radial trace transform
- **rad3d:** Prepares 3D dataset trace headers for radfilt. [p]
- **reflectivity:** Seismic modeling with the reflectivity method. [m]
- **specrat:** Water bottom deconvolution using simple multiple. [p]
- **sweeper:** Vibroseis correlation using deconvolution. [p]
- **timath:** Time domain panel processor toolbox program, currently including least-squares subtraction and DFT. [p]
- **vsp-ppnmo:** a method of correcting the normal moveout traveltimes of a P-P wave 3-D (R)VSP wavefield to the two-way traveltime corresponding to surface seismic. [p]
- **V(z) f-k migration:** 2D prestack P-P and P-S migration capable of very high accuracy for vertical velocity variations. [m]
- **waveheal:** wave front healing operator for smoothing scattering on stack sections. [p]
- **waveheal2:** wave front healing operator using 5 pts. [p]

Applications

- **AniZoeppritz Explorer:** The AniZoeppritz Explorer utility lends insight into the realm of materials displaying vertical transverse isotropy (VTI) and horizontal transverse isotropy (HTI). For VTI media it can display both the exact and linearized P-wave reflection coefficients. For HTI media one can explore the behaviour of the linearized P-wave reflection coefficient and compare it with values for an isotropic earth. It features interactively adjustable anisotropy parameters, gamma, delta, and epsilon, as well as the azimuthal angle of incidence.
- **anvel:** calculates anisotropic group and phase velocity with angle.
- **Elmo:** an elastic wavefield modelling package. It uses the phase shift cascade method to model wave propagation through 2-D horizontally layered media. Based on the elastic wave equation, the method propagates P and S wave potentials to model an earth response. Elmo includes parameters to reduce artifacts, and the ability to isolate various wavefield effects in order to partition a seismic response into component wavefields. As well as P and S potentials, Elmo can compute horizontal and vertical displacements. [m]
- **Energy Explorer:** Calculates the fraction of energy transmitted away from the interface as a function of angle for each mode. This provides valuable information complementary to that of the Zoeppritz Explorer.
- **Footprint:** Acquisition footprint calculation. [m]
- **gss:** P and S body wave synthetics using the Goupillaud state-space model.

- **hippo:** Hypocenter location using a fast marching method eikonal equation solver. [m]
- **Interface Parameter Calculator:** The Interface Parameter Calculator provides a convenient tool for converting between various representations of elastic interface data. One can readily convert from densities and velocities to ratios and contrasts, for instance, as is commonly done in AVO studies.
- Logsec: Generate well-log cross sections from geological model [m]
- Logedit: Edit well logs and tops [m, w]
- **QuadDes (formerly Design3C):** an acquisition geometry design package that computes and displays fold maps for P waves or converted waves recorded in multicomponent 3-D seismic surveys. [w]
- shraytrc: SH ray tracing in visco-elastic transversely isotropic media.
- Syngram (formerly Synth): calculates P-P and P-S synthetic seismograms based on raytracing with offset-dependent reflectivities. [m, w]
- Reflectivity Explorer: Displays large number of AVO-related approximations to the P-P reflection co-efficient for any combination of earth properties. The results can be displayed as functions of either angle or offset.
- Reflectivity Explorer (v. 2): Model seismic wave propagation in stratified earth models.
- Reflectivity Explorer (v. 3): A test version of the reflectivity explorer which includes a new approximation method.
- Refrac: refraction statics analysis [m]
- Spherical Wave Reflectivity Explorer: This explorer is modeled after the Zoeppritz Explorer. In this application, however, reflection coefficients are calculated for both plane waves and spherical waves.
- Spherical Zoeppritz Explorer: An interactive program to explore reflection coefficients calculated for both plane waves and spherical waves.
- tpsemblance: Parabolic Gauss-Seidel semblance-weighted Radon transform. [m]
- Waveleted: a Matlab module that allows the creation of numerous types of wavelets (Ricker, Bandpass, etc.) with a wide variety of phase and frequency control. [m, w]
- Wellpro: a full zero-offset VSP processing package running under Unix/X-windows.
- Zoeppritz Explorer: Visually explore Zoeppritz equation solutions with various parameter inputs.
- Zoeppritz Explorer (ASCII version): Identical to the former Zoeppritz Explorer except that it has a facility to send output to an ASCII file.
- **Zoeppritz Explorer 2.1:** This is the latest upgrade to the Zoeppritz Explorer. It allows one to plot against negative angles, and to plot complex reflectivities in three different modes: Cartesian, Polar, and Modified Polar.
- TI Explorer 1.0: This is similar to the older AniZoeppritz Explorer in that it allows one to plot reflection coefficients for both VTI and HTI media, but it now includes the exact HTI solution.
- HTI Explorer 1.0: This allows one to plot reflection coefficients for HTI media against azimuthal angle.
- Fluid Properties Calculator 1.0: This permits one to calculate properties of gas, oil and/or brine in a reservoir for use in fluid substitution problems.
- Hodogram Explorer 1.0: This permits one to convert trace data in ASCII form into hodogram crossplots. The polarization angle in each plane is calculated and displayed.

Utility Packages
- **editlines:** a general digital editing tool for line data. [m]

- mapview: creates a color map of gridded data. Arbitrary, randomly placed points may be superimposed. [m]
- crPerl: allows the use of perl scripts to modify trace headers and/or data within a ProMAX processing flow. [p, perl]
- slicetool: provides interactive 2-D viewing and manipulation of a random Earth Object. [m]
- surfview: provides an interactive, point & click interface to viewing and manipulating 3-D surfaces. [m]
- vp2vs: generates a shear-wave log from a P-wave log and a table of Vp/Vs ratios.[m]

Matlab Seismic Toolbox

The CREWES seismic toolbox is a collection of seismic processing routines, seismic data input/output, viewing routines and graphical utilities. This toolbox adds tremendously to the power of the Matlab computing environment, making it an almost ideal platform for the testing and development of new seismic processing techniques.

- **dataobjects:** routines for building complex data structures or 'objects'.
- dialogs: various user interface dialogs.
- geometric: tools for geometric problems such as 'find the closest point to a line', 'is a point inside a polygon', etc.
- inversion: two different 1-D inversions schemes, band limited integration, computing Rcs from impedance and the reverse.
- io: a collection of functions to read and write segy seismic and logs in LAS or GMA format.
- logtools: tools for manipulating well logs. These include: check shot corrections, Gardner's rule, log blocking, depth to time conversions, t-z curves from sonics, plotting tops, stretching logs, and making seismograms.
- raytrace: raytracing in a v(z) world for P-P, P-S and S-S. Automatic routines for P-P and P-S gathers.
- seismic: almost 100 tools for single channel seismic processing and time series analysis. Various decons, gain corrections, spectral analyses, resampling, wavelets, etc.
- **tools:** a collection of mostly GUI tools for manipulating and viewing surfaces, plotting seismic, manipulating vectors, etc.
- utilities: more seismic plotting, digital editing engine, zooming, selection box, interpolating, etc.
- velocity: velocity manipulation and conversion. Interval, average and RMS velocities are supported.

CREWES

RESEARCH REPORT
VOLUME 27 - 2015
CONTENTS

SUMMARY

The Consortium for Research in Elastic Wave Exploration Seismology (CREWES) invites organizations with an interest in exploration geophysics to participate in a one-year (renewable)[*] program of geophysical research. There have been exciting new scientific developments in the past year, notably in the areas of seismic inversion (full waveform inversion and inverse scattering), accelerometer analysis, land streamer data acquisition, continuous seismic monitoring, anisotropy analysis, depth imaging, 3C-3D surface seismic cases, geostatistical integration, and VSP analysis. These developments are being assessed in collaboration with the industry. The project personnel are enthusiastically continuing their research efforts in these and other areas.

The overall objective of the Project is to work with industry sponsors to conduct advanced geophysical research and education in areas crucial to resource exploration and development. We are focused on multicomponent and 3-D data acquisition, new and improved processing algorithms, and interpretational techniques aimed at enhanced 3-D petrophysical imaging.

Five faculty members in the Department of Geoscience at the University of Calgary are working directly on the Project with their associated graduate students and post-doctoral fellows. Eight staff members provide additional research expertise, and technical and administrative support. The CREWES Governance Board comprised of CREWES Executives and Industrial Associates provides strategic and technical counsel to the Project.

CREWES communicates research results to its sponsors through an active website, an annual Research Report, and a yearly Sponsors Meeting where the achievements of the preceding twelve months are presented. These and other benefits of sponsorship are included in the following list.

BENEFITS OF SPONSORSHIP

Each sponsor of CREWES:

i) has immediate access to the CREWES Research Collection (1622 research reports and 151 student theses), software, and CREWES News, through the web site (www.crewes.org)

ii) receives the yearly Research Report (approximately 90 chapters) on CREWES research activities, and the bi-annual CREWES Newsletter;

iii) receives releases of software developed by the Project;

iv) has access to detailed multicomponent field surveys acquired by the Project;

v) has access to physical modelling data (acoustic and elastic);

vi) is invited to continuing education seminars and courses on areas of recent technical development;

vii) is invited to the annual Sponsors Meeting where CREWES-generated research results are presented;

viii) has access to graduate-student theses and presentation abstracts;

Contract terms available from one to five years and in all cases sponsor may back out at the end of any year

ix) has the opportunity to develop joint projects of mutual interest; and

x) has a chance to become acquainted with graduate students as potential future employees.

FINANCING

We have received a one-year renewal* from our existing sponsors and seek participation from new sponsors. Sponsorship will continue on an annual basis, with commitment for one year at a time. New sponsors receive access to previous research reports and software releases on the CREWES website.

Sponsor Fees 2016

- **Main:** $49,000 CAD - companies with an annual gross revenue over $50 million Canadian

- **Intermediate:** $37,000 CAD - companies with an annual gross revenue over $10 million and less than $50 million Canadian

- **Entry*:** $17,500 CAD - companies with an annual gross revenue under $10 million Canadian

 *Conditions
- Entry: Sponsoring companies at this level are not eligible to have a delegate on the CREWES Governance Board.

Current CREWES Industry Sponsors

Acceleware Ltd.	Petrobras
BHP Billiton Petroleum (Deepwater) Inc.	Petronas Carigali SDN BHD
CGG	Repsol Oil and Gas Canada Inc.
Chevron Corporation	Sinopec
Devon Energy Corporation	Suncor Energy Inc.
Halliburton	Tullow Oil p.l.c.
INOVA Geophysical Equipment Ltd.	
Nexen Energy ULC	

Other Funding

Since 1994, CREWES has been successful in obtaining Natural Sciences and Engineering Research Council (NSERC) funding to match a portion of the industry contributions. The support received from NSERC is equal to approximately thirty five percent of the total Project funding. The NSERC funds are also used to conduct advanced applied geophysical research, and support the CREWES goals. In June of 2014, CREWES received an NSERC Collaborative Research and Development grant in the amount of roughly $391,000 per year for five years.

RESEARCH DIRECTIONS

The table of contents of the 2015 CREWES Research Report, attached, indicates the current scope of research being conducted by project personnel.

PERSONNEL

CREWES is led by the following faculty members of the Department of Geoscience at the University of Calgary:

- Director: Dr. Kris Innanen
- Associate Directors: Dr. Don Lawton and Dr. Daniel Trad
- Associated Faculty: Drs. Michael Lamoureux, Larry Lines
- Emeritus Director: Dr. Gary Margrave

These scientists, with input from representatives of sponsor companies, set the scientific direction of the project that, in turn, determines its budget and organization. This direction and management is in accordance with operations of the Department of Geoscience under its head and the rules and provisions of the University of Calgary.

A number of graduate students are supervised and supported by the Project, either fully or in part. The students' research projects are compatible with the research directions of CREWES and the results of their research are shared with sponsors.

Active Graduate Students (Degree Program)

Winnie Ajiduah (Ph.D.)	Junxiao Li (Ph.D.)
Khaled Al Dulaijan (Ph.D.)	Emma Lv (M.Sc.)
Khalid Almuteri (M.Sc.)	Andrew Mills (M.Sc.)
Tim Cary (M.Sc.)	Michelle Montano (M.Sc.)
Raúl Cova (Ph.D.)	Shahpoor Moradi (Ph.D.)
Matt Eaid (M.Sc.)	Evan Mutual (M.Sc.)
Dennis Ellison (M.Sc.)	Davood Nowroozi (Ph.D.)
Ali Fathalian (Ph.D)	Wenyong Pan (Ph.D.)
Adriana Gordon (M.Sc.)	Sergio Romahn (Ph.D.)
Marcelo Guarido de Andrade (Ph.D.)	Eric Rops (M.Sc.)
Bobby Gunning (M.Sc.)	Tyler Spackman (M.Sc.)
Heather Hardeman (Ph.D.)	Jian Sun (Ph.D.)
Nadine Igonin (Ph.D.)	Ron Weir (M.Sc.)
Andy Iverson (M.Sc.)	Kiki Xu (M.Sc.)
Scott Keating (Ph.D.)	

Staff members supported by the project conduct research, and provide technical and administrative support.

Staff Members

Laura Baird
    Program Manager

Kevin Bertram
    Research Technologist

Malcolm Bertram
    Acquisition Research Scientist

Pat Daley, Ph.D.
    Research Geoscientist

Kevin Hall, M.Sc., P. Geoph.
    Technical Manager

Dave Henley, M.Sc.
    Research Geophysicist

Helen Isaac, Ph.D.
    Research Scientist

Joe Wong, Ph.D.
    Research Geophysicist

CREWES students and staff also benefit from a team of expert technical advisors who volunteer their time to the benefit of our graduate students and their research.

Technical Advisors
Andreas Cordsen
Sam Gray, Ph.D.
Roy Lindseth, LL.D, P. Geoph.
Faranak Mahmoudian, Ph.D., P. Geoph.
Claude Ribordy, Ph.D.
Brian Russell, Ph.D.
Robert Stewart, Ph.D.
Xiucheng Wei, Ph.D.
Matt Yedlin, Ph.D.

2016 CREWES SPONSORS MEETING

November 30, December 1-2, 2016   Banff Park Lodge - Banff, Alberta, Canada

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CREWES faculty, students, and staff at the University of Calgary, September 2016

Effective July 2016

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