



Present and Future

What are we?
Where are we?
and
Where are we going?

www.crewes.org

CREWES (1989-present)

Consortium for Research in Elastic-Wave Exploration Seismology

- Consortium: University + Industry + Government.
- Research: Since the majority of our sponsors are in the Oil and Gas industry, our research must be applied and useful.
- Elastic-Wave: We emphasize multicomponent and both P and S waves.
- Exploration: Interpret this generally as "looking underground".
- Seismology: While we do work with non-seismic methods (well logs, gravity, etc) seismic exploration is our focus.

CREWES

CREWES is the oldest research group at the UofC and one of the largest.

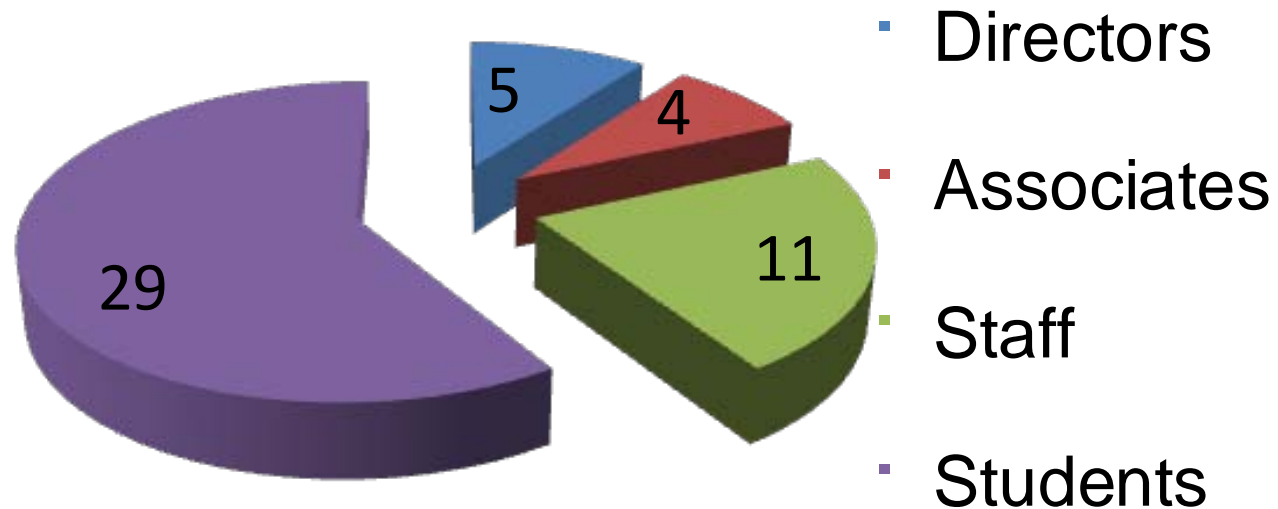
Compared to other seismic consortia (worldwide), CREWES stands out with its field ability, breadth of research, history of innovation, and extensive industry connections.

***CREWES* is People**



CREWES Personnel as of September 2014

□



CREWES Faculty, Adjuncts and Scientists

Dr Gary Margrave,	Director
Dr Don Lawton,	Associate Director
Dr Kris Innanen,	Associate Director
Dr Larry Lines,	Adjunct Director
Dr Michael Lamoureux,	Adjunct Director
Dr. Roy Lindseth	Technical Advisor
Dr. Brian Russell	Adjunct (CGG)
Dr Robert Stewart,	Collaborator (UofH)
Dr. Matt Yedlin	Collaborator (UBC)

CREWES Staff

1. **Laura Baird**, Project Manager
2. **Dr. John Bancroft**, Adjunct Faculty, Senior Research Scientist
3. **Kevin Bertram**, Research Technologist
4. **Malcolm Bertram**, Acquisition Research Scientist
5. **Dr. Pat Daley**, Research Geoscientist (seismic theory and modelling)
6. **Eric Gallant**, Research Technologist (equipment specialist)
7. **Kevin Hall**, Technical Manager
8. **David Henley**, Research Geophysicist (noise and near surface specialist)
9. **Dr. Helen Isaac**, Research Scientist (processing)
10. **Dr. Peter Manning**, Post Doc (elastic wave modelling)
11. **Dr. Joe Wong**, Research Geophysicist (borehole, physical modelling)

Virtually all staff have considerable industry experience.

Active CREWES Students

- Winnie Ajiduah, PhD.,
- Khaled Al Dulaijan, Ph.D.,
- Tunde Arenrin, Ph.D.,
- Rafael Asuaje, M.Sc.,
- Raúl Cova, Ph.D.,
- Jean Cui, Ph.D.,
- Tianci Cui, M.Sc.,
- Jessica Dongas, M.Sc.,
- Sina Esmaeili, M.Sc.,
- Marcelo Guarido, Ph.D.,
- Saul Guevara, Ph.D.,
- Bobby Gunning, M.Sc., **NEW**
- Shahin Jabbari, Ph.D.,
- Scott Keating, M.Sc., **NEW**
- Hassan Khaniani, Ph.D.,

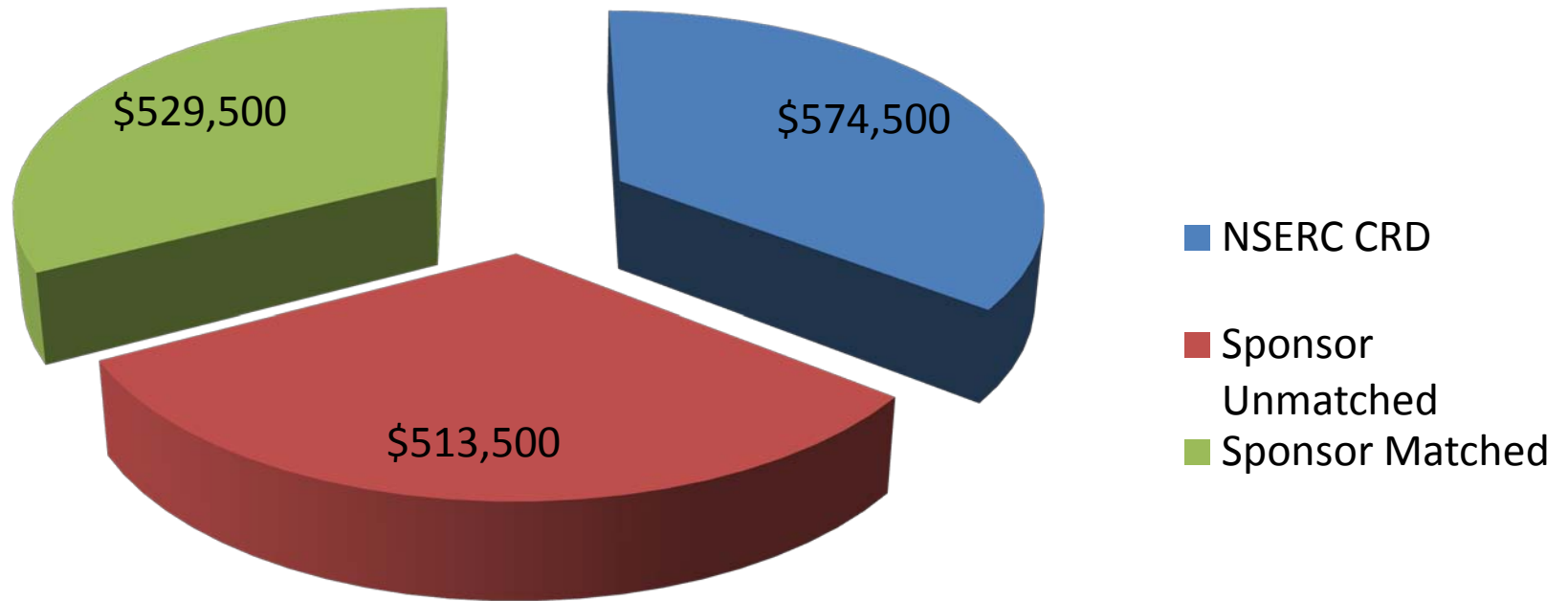
**13 M.Sc. +
16 Ph.D. =**

29 active students

- Jesse Kolb, M.Sc.,
- Junxiao Li, Ph.D., **NEW**
- Michelle Montano, M.Sc.
- Shahin Moradi, Ph.D.,
- Shahpoor Moradi, Ph.D.,
- Davood Nowroozi, Ph.D.,
- Penny Pan, M.Sc.,
- Wenyong Pan, Ph.D.,
- Chris Petten, M.Sc.,
- Sergio Romahn, Ph.D., **NEW**
- Eric Rops, M.Sc., **NEW**
- Adrian Smith, M.Sc.,
- Jian Sun, Ph.D.,
- Bona Wu, M.Sc.

CREWES Revenue

Total Revenue for 2013: \$1,624,534



Federal Government Support NSERC CRD July 2014

Towards Broadband Multicomponent Seismology and Practical Iterated Inversion

\$449,000 annually for 5 years. Matches an equal amount of Sponsor dollars, minus in-kind donations.

CREWES has had CRD grants continuously since 1994

CRD= Collaborative Research and Development Grant.

Sponsorship Fees 2014

- **Main:** \$49,000 CAD per year. This is for companies with an annual gross revenue over \$50 million
- **Intermediate:** \$37,000 CAD per year. This is for companies with an annual gross revenue between \$1 million and \$50 million
- **Entry:** \$15,000 for companies with annual gross revenue under \$1 million

Fees were last increased in 2012

CREWES Sponsors 2014

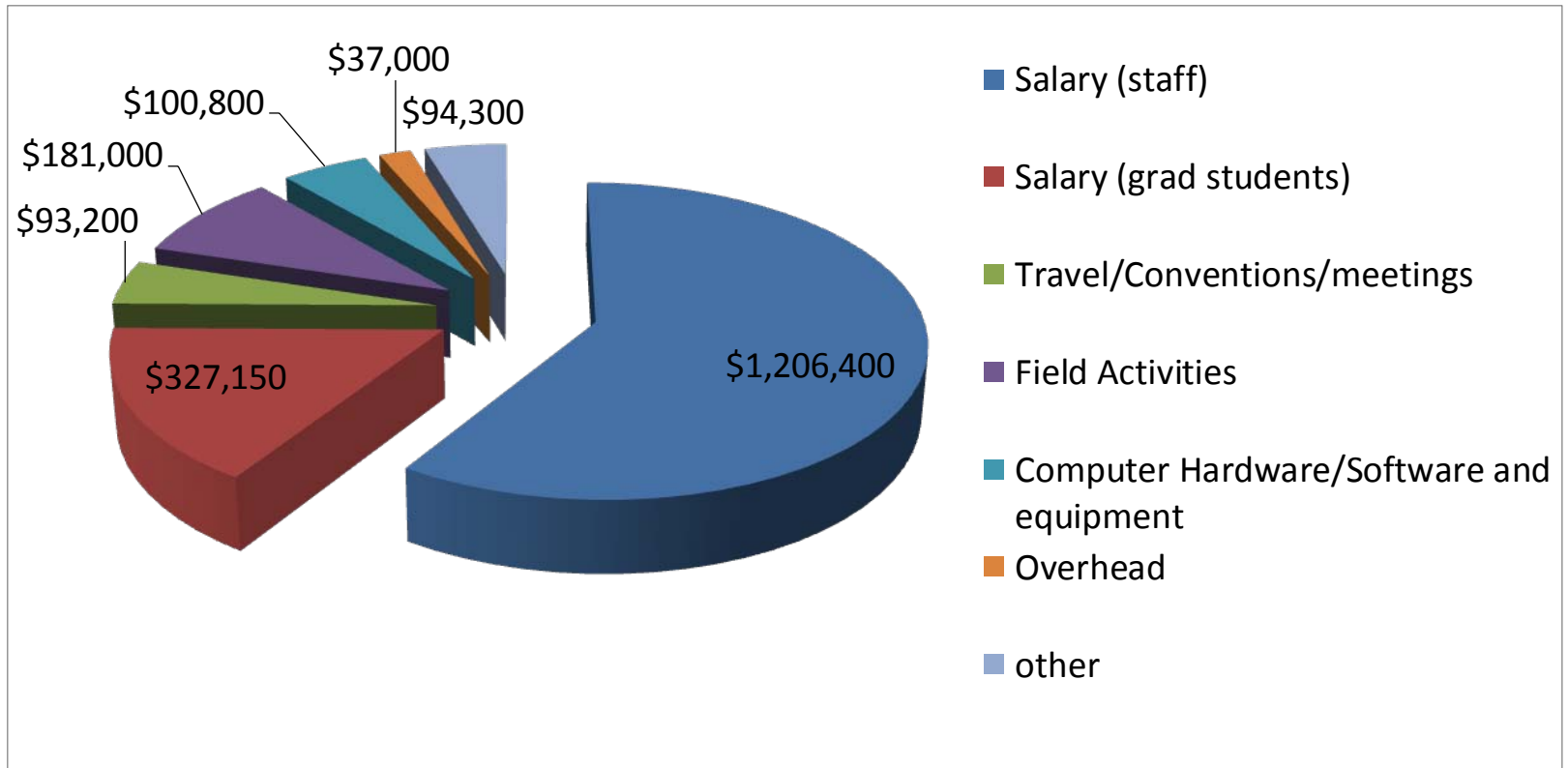
- Acceleware
- BHP Billiton Petroleum (Americas) Inc.
- CGG
- Chevron Corporation
- ConocoPhillips
- Devon Energy Corporation
- Exxon Mobil Corporation
- Geokinetics Inc.
- Halliburton/ Landmark Graphics Corporation
- Husky Energy Inc.
- INOVA Geophysical Equipment Ltd.
- Nexen Inc.

CREWES Sponsors 2014(continued)

- Northwest Geology Institute, CNPC
- Petrobras
- PTT Exploration and Production Public Company Ltd.
- Saudi Aramco
- Sensor Geophysical Ltd.
- Shell Canada Limited
- Sinpoec
- Suncor
- Talisman Energy Inc.
- Tullow Oil p.l.c.

Total of 22 sponsors

CREWES Expenditures 2013



Historical Highlights

- 1989 CREWES founded by Stewart, Lawton, and Brown
- 1994 First NSERC grant
- 1995 Blackfoot 3C-3D, Margrave joins
- 1997 Lines joins
- 2001 Bus ride back from San Antonio
- 2005 Seismic acquisition system
- 2006 Priddis test site
- 2008 Stewart departs, Margrave becomes Director
- 2009 CREWES is awarded biggest NSERC CRD grant to date
- 2009 Innanen joins
- 2011 Hussar Low Frequency Shoot
- 2012 Priddis Shoot
- 2013 Drilling and instrumenting Priddis boreholes
- 2013 25th Anniversary!
- 2014 CRD awarded for five years – now in 20th consecutive year of NSERC funding

CREWES Annual Cycle

- Nov.-Dec.: Sponsors Meeting. 2 Days of presentations and sponsor interaction. **This year: December 3-5 (Wed-Fri).**
- May: GeoConvention (CSEG). CREWES presents work shown to sponsors previously.
- June: EAGE Convention. Same as CSEG.
- Sept.-Nov.: Prepare research reports for annual Sponsor's Meeting
- Sept.-Nov.: SEG Convention. CREWES presents work shown to sponsors the previous year.

Golden rule: The Sponsors should see it first.

CREWES Strengths

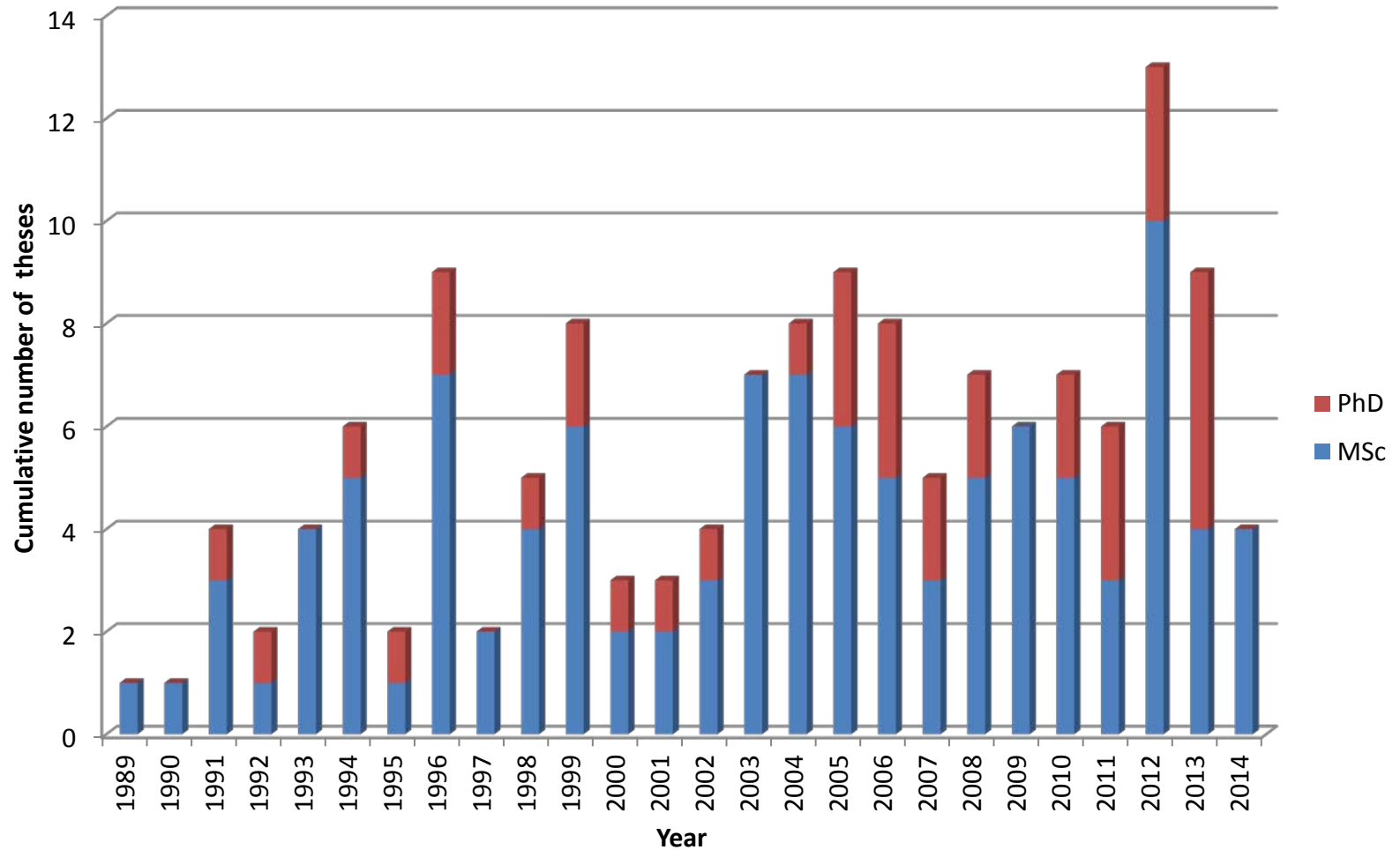
- Our People
 - Extensive industry experience (faculty and staff)
 - Strong graduate student group
- Our Sponsors
 - Broad industry support (local and beyond)
 - Government and University support
- Our Skills
 - Multicomponent recording
 - Converted wave (P-S) imaging
 - Imaging algorithms (P-P and P-S)
 - Seismic acquisition
- Our Toys
 - Seismic acquisition system
 - Downhole tools
 - Physical modelling facility
 - Parallel computer cluster

CREWES Deliverables to Sponsors

- Research reports on timely subjects
- Theses
- Software
- Data from field experiments and modelling
- Highly trained people for industry and academia

Research Productivity

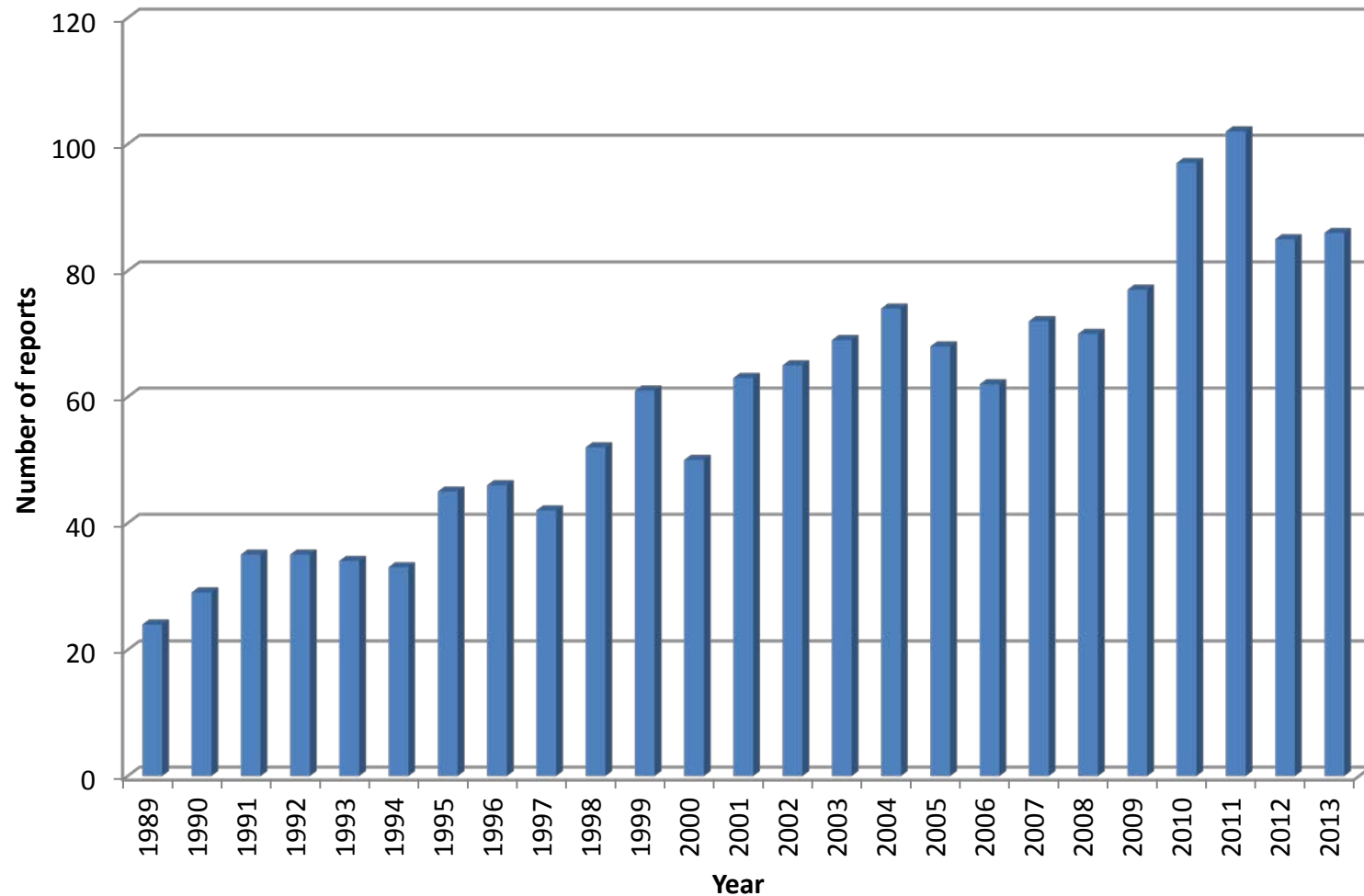
Number of CREWES theses per year



Project lifetime totals: 107 MSc, 36 PhD

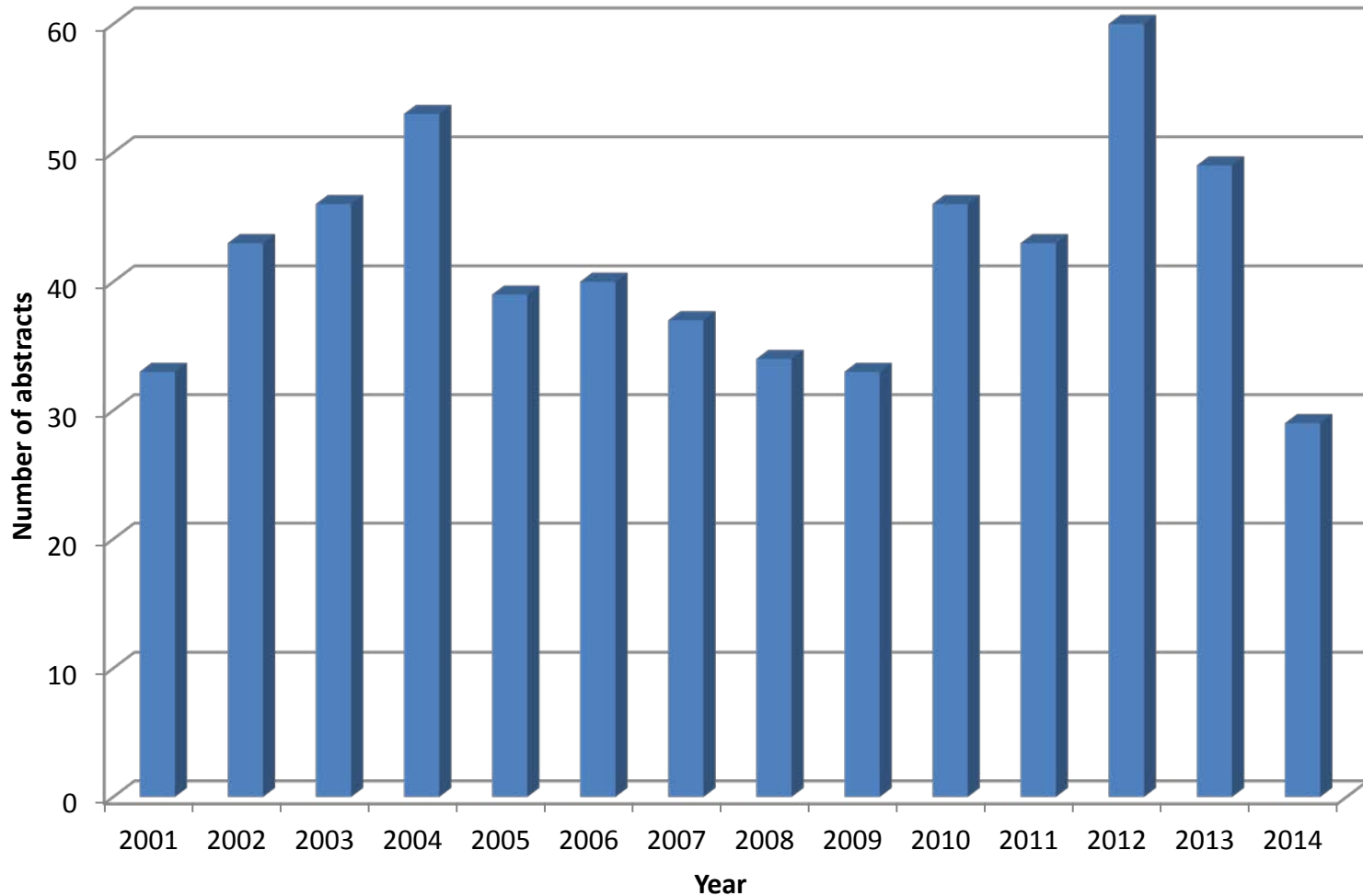
Research Productivity

Number of CREWES reports per year



Research Productivity

Number of CREWES conference abstracts per year



CREWES: Raison d'être

- The inversion of seismic data for rock and fluid properties is a ***grand challenge*** problem of science.
- The problem is highly nonlinear, overly sensitive to noise, and hugely computationally intensive.
- While it may never be solved, incremental advances have large, direct economic benefits.

Research Themes

- Seismic acquisition, multicomponent data
- Seismic data processing
- Seismic imaging
- Maximizing fidelity and bandwidth
- Incorporation of well logs and other supplemental data
- Inversion for lithology and pore fluids
- Reservoir analysis and optimization: time-lapse seismology
- Physical and numerical seismic modelling
- Instrument design and testing

Research goals

- Higher resolution seismic images
- More reliable seismic amplitudes
- Improved inversion for rock and fluid properties of reservoirs
- Better repeatability of time-lapse seismic

Previous CRD (June 2009-May 2014)

Improved Seismic Imaging for Reservoir Monitoring and Sustainable Energy Development

Emphasis on:

- Physical and numerical modelling
- Creation of 3D anisotropic imaging engine
- Quantitative assessment of acquisition geometries
- Moving from imaging to inversion, from subsurface morphology to subsurface rock properties
- Controlled field experiments to benchmark inversion methods
- Quantitative estimation and assessment of reservoir properties
- Field trials of gas injection monitoring: time-lapse seismology

New CRD Proposal (5 years)

Towards Broadband Multicomponent Seismology and Practical Iterated Inversion.

- Focus on land data.
- Addresses major roadblocks to *full-waveform inversion (FWI)*. Adapt techniques and algorithms from Standard Methodology (SM).
- Proposes development of *Iterated Modelling, Migration, and Inversion (IMMI)* as a modification of FWI using existing practical techniques. (deconvolution, prestack depth migration, impedance inversion, well control).
- Incorporates targeted field experiments.
- Continues emphasis on multicomponent recording on land and all aspects of data processing.

Vision of the new Proposal

Towards Broadband Multicomponent Seismology and Practical Iterated Inversion.

Implement seismic inversion by building on present practice and incorporating the latest developments from theory. The envisioned inversion methodology will:

- 1. Be iterative*
- 2. Incorporate the best techniques of modern practice*
- 3. Include well tying, data matching, and other constraints*
- 4. Accommodate advanced physical models*
- 5. Provide estimates of lithology and pore-fluid properties*
- 6. Include multicomponent wavefields*
- 7. Follow the vision of full-waveform inversion*
- 8. Be tested with field, lab and synthetic data*
- 9. Be practical*

Upcoming Events

Seismic shoot at Priddis

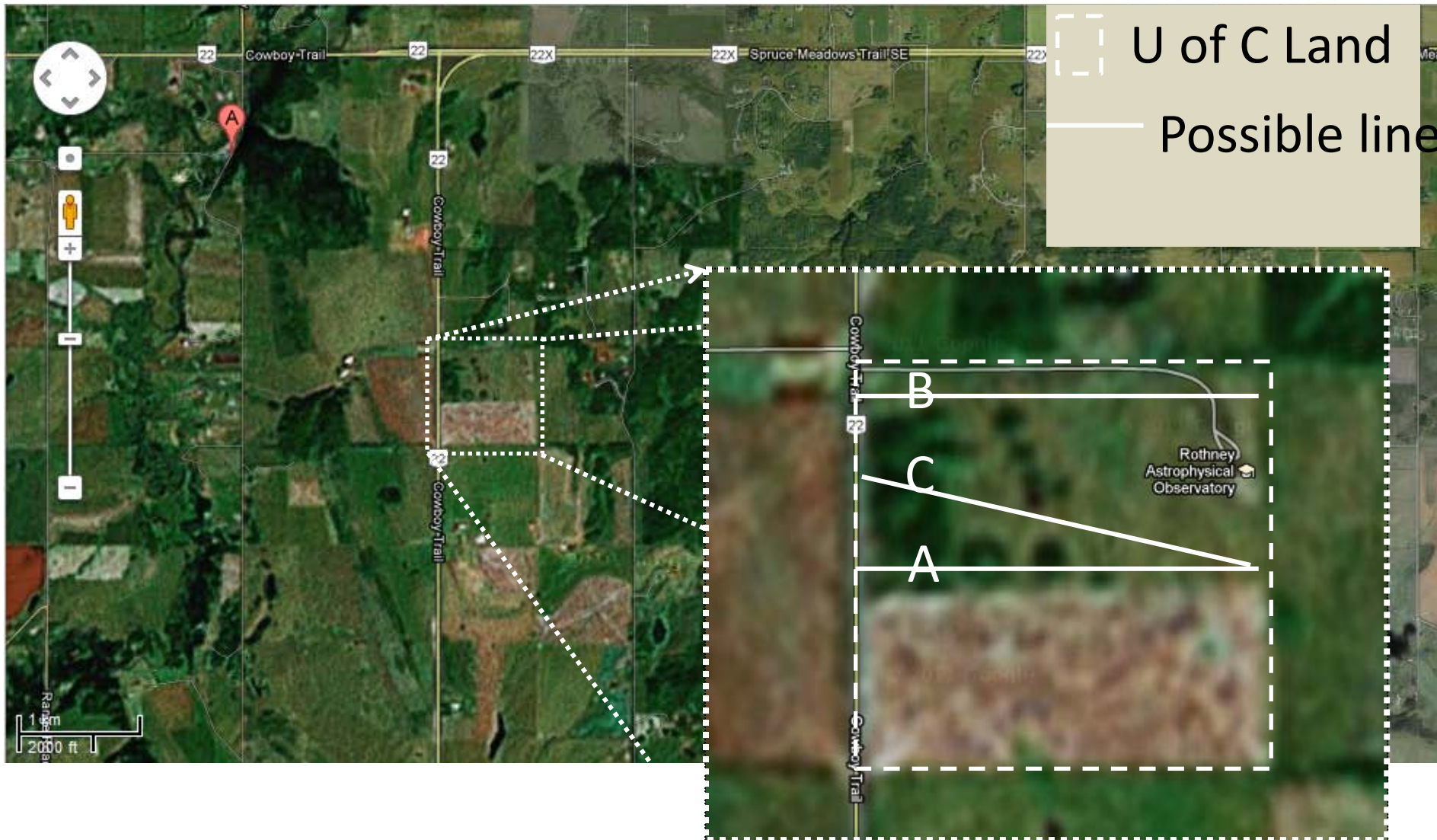
Layout and shothole drilling mid-October

Shooting early November

SEG in Denver Oct 26-31

Sponsors meeting, Dec 3-5

RAO Site (Near Priddis)



Airphoto



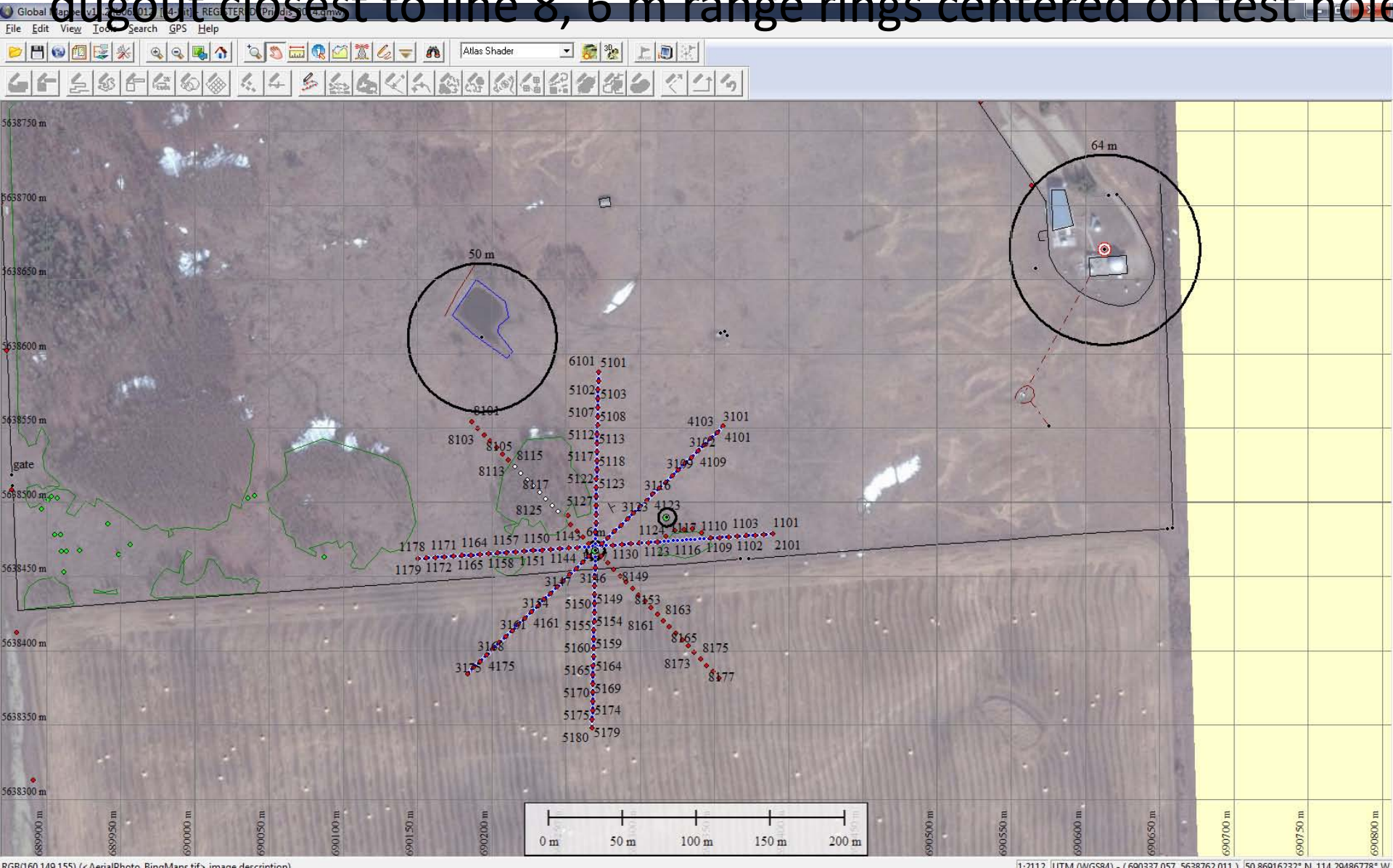
Geometry

- Line length = 240 m
- Receiver spacing = 3 m, station # increments by ones. 80 receivers (8 cables) per line. Blue dots on maps
- Source spacing = 6 m, station # increments by twos. Nominal 41 shot point locations per line, centered on testhole 1, with exception of rec/src lines 1&2 which are offset 2.5 m north. Red dots on maps

Geometry

- Permitted linename = line#
- TH6 = rec,src lines 1,2
 - Offset shots 2117-2125 (5). Dropped shots 2139-2143 (3). 38 shots
- TH1-02 = 3,4
 - Dropped shots 4141(1). 40 shots
- TH1-01 = 5,6
 - Dropped shots 6139-6132 (3). 38 shots
- TH1-04 = 7,8
 - Offset shot 8131 (1), Dropped shots 8141, 8115-8129 (white dots) (9). 32 shots
 - Total number of shots = $38+40+38+32 = 148$ shots

Overview: 64 m range ring on RAO water well, 50 m range ring on dugout closest to line 8, 6 m range rings centered on test hole



Conclusions

- Exciting geophysics is coming soon.
- Take part in CREWES activities.
- Respect our Sponsor agreements
- Where possible, direct your research towards our groups goals.
- Pay attention to upcoming announcements.