# CREWES in the field: 2019 overview

Kevin L. Bertram*, Kris Innanen, Kevin W. Hall, Marie Macquet, Malcolm Bertram, and Don C. Lawton

## ABSTRACT

Simulated data is useful for testing various processing methods, but there is still a huge advantage to using data acquired in the “real world”. CREWES has a long history of acquiring and processing field data. With access to several different acquisition tools and instruments several different experiments can be carried out. This year fieldwork acquisition was exclusively done at the CaMI FRS.

Projects that CREWES has been involved with this year include: a) the setup of several passive monitoring three component recording stations; b) an acquisition experiment with a repeatable source location before, during, and after carbon dioxide injection into an underground reservoir; c) the 2019 Geophysics Undergraduate Field School with the University of Calgary’s Geoscience Department; d) the setup of repeatable source locations for a walk-away/walk-around VSP.

## INTRODUCTION

Although the number of projects directly carried out by CREWES has decreased somewhat this year, there were some longer term/repeating research trips done. All field research was done exclusively at the Containment and Monitoring Institute’s Field Research Station (CaMI.FRS).

The first project was the setup of passive monitoring stations in the field.

The second project was a time lapse experiment acquiring data before, during, and after $CO_2$ injection. This survey used permanently installed three component geophones on the observation well at CaMI.FRS. The source for this experiment setup in a known repeatable location.

The second project was a demonstration at Earth Science for Society in March. CREWES had been attending this exhibit for several years now. This is a simple demonstration of some of the tools that are used for seismic acquisition and monitoring.

The third project was the University of Calgary’s undergraduate field school in late August. This class serves as an introduction to field data acquisition with a hands on approach. The seismic acquisition portion was a 3D survey with single component geophones.

The final project was the setup of a repeatable walk-away/walk-around VSP centred around the geophysical observation well at CaMI.FRS.

## TOOLS

Most of the field tools that CREWES uses are owned by the Seismic Group. The primary system used is an 600 channel Aram Aries (now Inova) system. This system contains:

- 600 1C SM24 10Hz geophones
- 75 Aries eight channel Remote Acquisition Modules (RAMs)
- 75 Aries single component cables with 15M spacing
- 10 Aries Line Taps
- An Aries Seismic Processing Module Lite (SPML) recording computer
- 100 batteries

There are also VibPro and ShotPro II source controllers which allow the use of both vibroseis and impulse sources. The system has been upgraded a few times and now has the capability of recording three component geophones using twenty four channel RAM. This year another sixty eight channel RAMs were acquired. Unfortunately this system has reached end of life and so the acquisition of these RAMs really helps in keeping this system running.

At the same time that the Aries system was acquired a Geometrics Geode system was purchased. This system is more compact and portable for use in more remote areas. The current setup has six Geodes that record twenty four channels of data. This data is not stored in the Geode but is networked to a ruggedized laptop for control and data recording. The receiver spacing on the cables is much shorter than the Aries and this system is typically used for refraction surveys.

Also available is a Geostuff downhole tool. This is a three component geophone that can be used with either the Aries or the Geometrics systems. Typically it gets used with the Geodes. The downhole tool has an electrically driven bow spring clamp to secure it against the walls of an observation well.

The most current recording system that is being used by CREWES belongs to CMC (part of CaMI) and is the Inova Hawk nodal system. This runs cableless and uses GPS timing to sync source start times to the records produced. The nodes simply start recording when they are set up and keep going until either the battery dies or the storage media is full. The data is downloaded as a single file for each node and can then be parsed into shots based on a shot log created by the source controller.

On the source side of things the most famous source used is the IVI Envirovibe. This is often pictured in CREWES posters and on the website. It is a small vibroseis unit designed to be low impact and able to navigate where larger vibes are unable to go. It even gets used sometimes within city limits with no drama.

The next step down is the nitrogen spring thumper. This is an impulse source that hits an aluminum foot with a hammer to transmit energy into the ground. This source has the ability to adjust the angle at which the hammer hits the foot, making this unit able to produce P and S waves.

The smallest unit on hand is a simple hammer and plate.

The last major component used during acquisition surveys is a Hemisphere differential GPS system. Great accuracy can be obtained by using a base station at a known location transmitting corrections based on knowledge to a rover GPS unit.

This equipment is stored in a large bay on university property, Figure 1.

FIG. 1. Equipment storage bay.

## LOCATIONS

All field acquisition projects took place at the CaMI.FRS, which is located outside the town of Brooks, Alberta, Figure 2. Last year the University of Calgary's geophysics field school was relocated from the Pincher Creek area to this location due to forest fire danger. This location has proved to have good data and it is also easier to permit as that there is a long term permit that just needs to be reactivated.


FIG. 2. CaMI.FRS southwest of Brooks Alberta.

## PASSIVE MONITORING AT FRS

CREWES aided in the setup, transport, deployment, and data collection of three component receivers at FRS. The receivers used were analog geophones connect to the Inova Hawk nodal system (Macquet et. al. 2019).

Setup of this survey required that a survey file first be acquired. This was created by CREWES researcher Mari Macquet based on many years of previous surveys. This file is loaded into the project and then the data loaded into the Hawk nodes along with various other parametres that determine the nodes behaviour.

The batteries for the nodes also need to be charged and packed for transport. Because the batteries are of the lithium ion type they fall under the dangerous goods category and as a result special care and paperwork is required when transporting them.

Deployment is fairly straight forward. First the location for the receiver needs to be determined by GPS, in this case the field computer supplied with the Hawk nodes. Once the location is determined a hole is made using an auger to plant the geophone in. With the geophone planted level and oriented to magnetic north is can then be connected to the Hawk node. The battery is then connected to the node and the system powers up. Once the node has gone through its power up and self tests it starts to record, Figure 3. At this point the field computer can be connected wirelessly to it and the node will give its status. At this point the node needs to be told which receiver point it is at. On surveys with large receiver spacing this isn't a problem. However, CREWES tends to use smaller receiver spacing which can cause the nodes to pick a location that belongs to another node. This connection with the field computer gives the opportunity to tell the node which location it should snap to.

FIG. 3. A Hawk node, geophone and battery recording.

The Hawk then need to be swapped out for longer surveys as their batteries get depleted and/or their data storage fills up. The geophone stays in place, but other than that the deployment is the same as the initial setup. Hawk and dead batteries are returned to the storage bays.

The Hawk are then connected to the same computer that was used for the initial programming and data is then downloaded, Figure 4. The data downloaded is a single long file per node with all the data collected since power up. This data can then be manipulated into smaller batches by setting up a shot table to break the data up into intervals of time. Using a microseismic option allows for the last sample of the previous record to overlap with the first of the current.

FIG. 4. The Hawk programming and download rack on the right.

## EARTH SCIENCE FOR SOCIETY

CREWES volunteers at Earth Science for Society (ESFS) every year. This is an interactive demonstration of the geosciences held in Calgary which is open to the public. Along with the general public there are several students from local schools that are brought in to be exposed to potential career paths as well as general information about earth sciences.

Each year CREWES brings a line truck filled with some of the tools used in acquisition. There is a ground penetrating radar cart, a seismometer, a three component geophone and a beam with sixty geophones connected to Geodes with a live display on a laptop, Figure 5.


FIG. 5. Top: The CREWES display. Bottom: CREWES Postdoctoral Researcher Marie Macquet demonstrating the Geode system to students.

## TIMELAPSE DURING $CO_2$ INJECTION

Based on a previous experiment where microbubbles in water affected seismic data an experiment nick named "Tiny Bubbles" was carried out (Innanen et. al. 2019). This experiment required that the source and receivers be stationary throughout. A location was picked for the source and the Envirovibe was parked over it, Figure 6. Once the pad was lowered it wasn't raised again until the experiment was over.

FIG. 6. The pad location was very clearly marked for this experiment.

The receivers were the permanently installed three component geophone cemented to the outside of the geophysics observation well. The geophones were recorded using the Geometric Geodes.

First a number of shots were acquired to obtain a baseline. The $CO_2$ injection was then started and more shots were acquired. Once the pump was shut off more shots were acquired again. Shots were taken long after the pump was shut off to acquire data as the system settled back to baseline.

There was an issue with sixty hertz noise in the data, Figure 7. It was determined that this was being introduced by the battery chargers for the Geode batteries. To reduce the noise the batteries were taken off charge during the data acquisition, Figure 8.

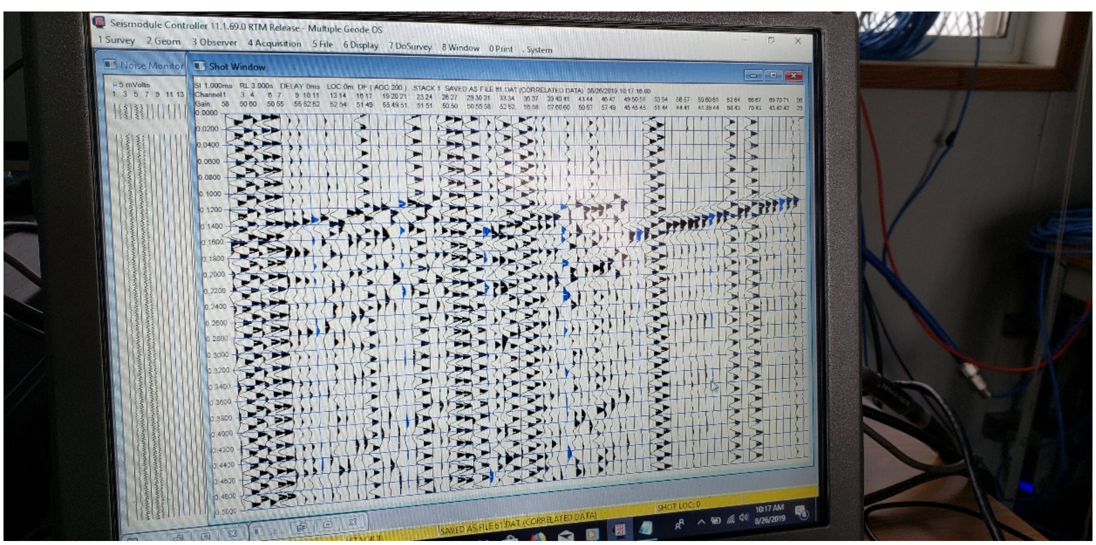


FIG. 7. Seismic record with sixty hertz noise induced by battery chargers attached to the Geode system.

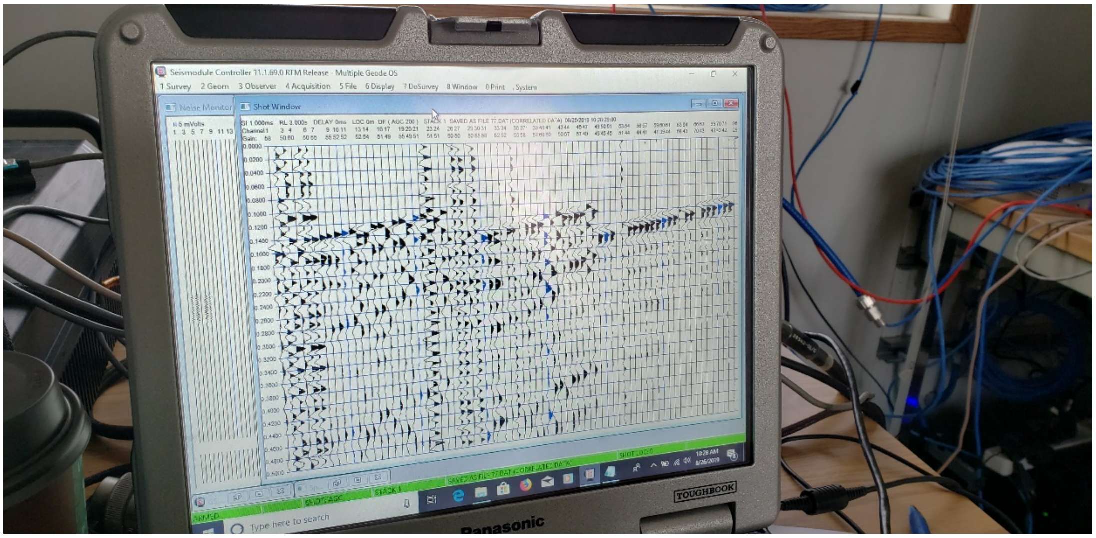


FIG. 8. Seismic record without the battery chargers attached to the Geode system, the sixty hertz noise is gone.

## FIELD SCHOOL

The University of Calgary remains one of the few, if not only, post secondary education facility with access to industry grade geophysics acquisition equipment. This offers a tremendous advantage for graduates of the geophysics program in that they have exposure and experience with how data is acquired. This provides them with an understanding of how real world situations can affect the data that they are looking at.

Like last year this course was run at the CaMI.FRS, Figure 9. Unlike last year this was planned from the beginning. Although the Pincher Creek area is more scenic with the mountains nearby the data is far superior in raw form at this location. The trailer classroom on site also provided a good place to discuss methods and data as well as shelter from the elements.

FIG. 9. The recorder truck parked at CaMI.FRS. Having power available on site meant that the generator on the back on the truck did not need to be run.

The focus of field school is for the students to perform all the setup, layout, acquisition, and clean up of the equipment to collect data. Although CREWES members focus on the seismic portion of the experience assistance is provided for the entire course.

The layout of the sources and receivers were the same as the previous year, however instead of starting from the north the layout started from the south. By combining both this year's and last year's field schools there should be a fairly complete 3D dataset for this area. Single component geophones were used for this survey.

On the first day members of CREWES as well at teaching assistants travelled directly to the site and flagged the first receiver/shot line. The firs line of geophones were then laid out and connected to the recording system. This allows for the first group of students in seismic recorder portion to start acquiring data right away while another group laid out the next line.

Every day started with a safety tail gate meeting. Once this was complete the students broke off into their groups and started their activities. The activities included:

- Seismic reflection recording crew which would record and check data while instructing the source (Envirovibe) on where it should be while troubleshooting and maintaining the receiver lines and performing some light interpretation of the recorded data, Figure 10.

- Seismic reflection field crew which would flag, lay out, pick up, and survey receiver lines.

- Refraction which would lay out a small refraction survey using both hammer and thumper sources and then interpret the data.

- VSP survey which would use a downhole tool to record data with both hammer and thumper sources.

- ERT which would layout electrodes and collect data.

- Gravity which did a brief gravity measurement near the trailer.

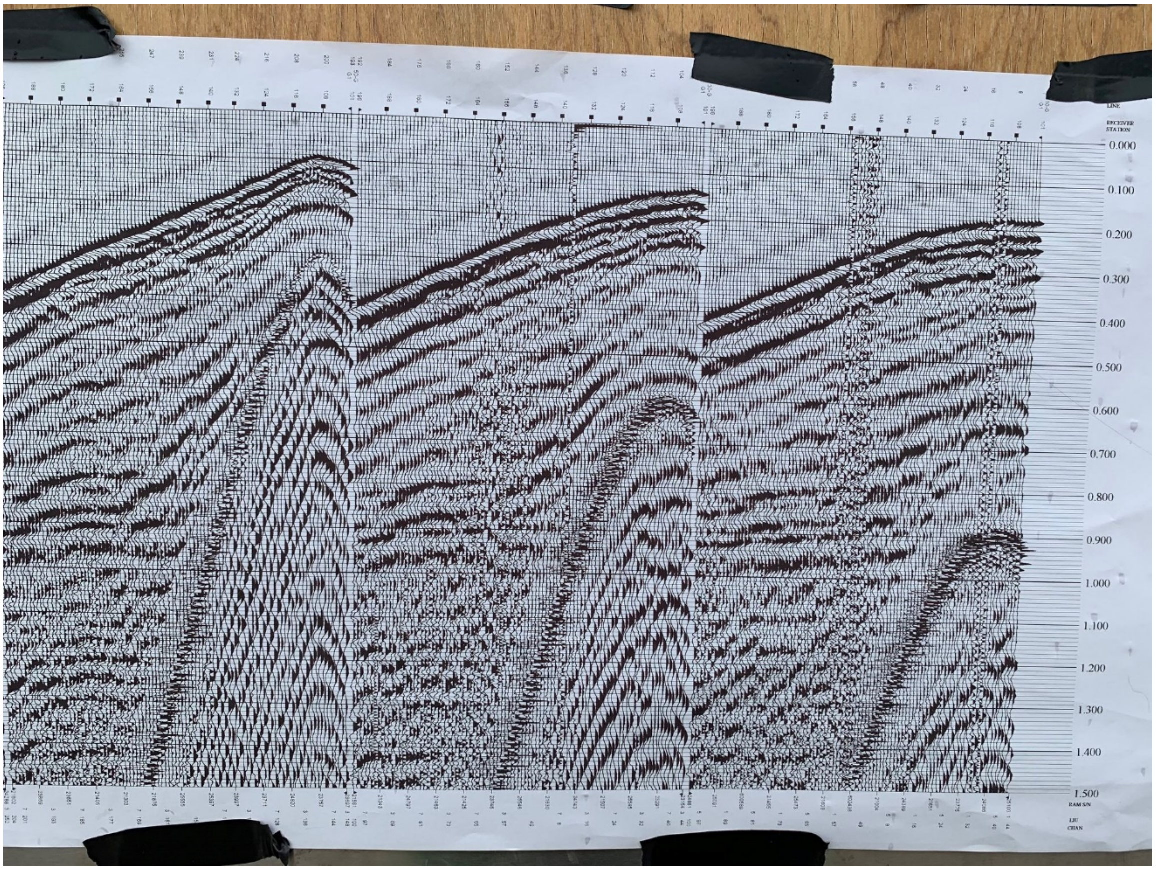

FIG. 10. A print out of data recorded at field school. Some questions that were asked include: what are the first break velocities?; based on the data alone what is the distance between lines?; what is the cone visible on each line?; are there any reflections present and if so how deep are they?

## SETUP OF A REPEATABLE VSP SURVEY

With the permanent installation of a geophysics test well there is a desire to be able to run a repeatable walk away/walk around VSP. This would allow tests to be carried out to compare different DAS interrogators using the fibre down the well. Two source lines that intersect on the well were flagged by pounding lath into the ground. A circle around the well at a distance of 120 metres with ten degree spacing was also marked out, Figure 11.

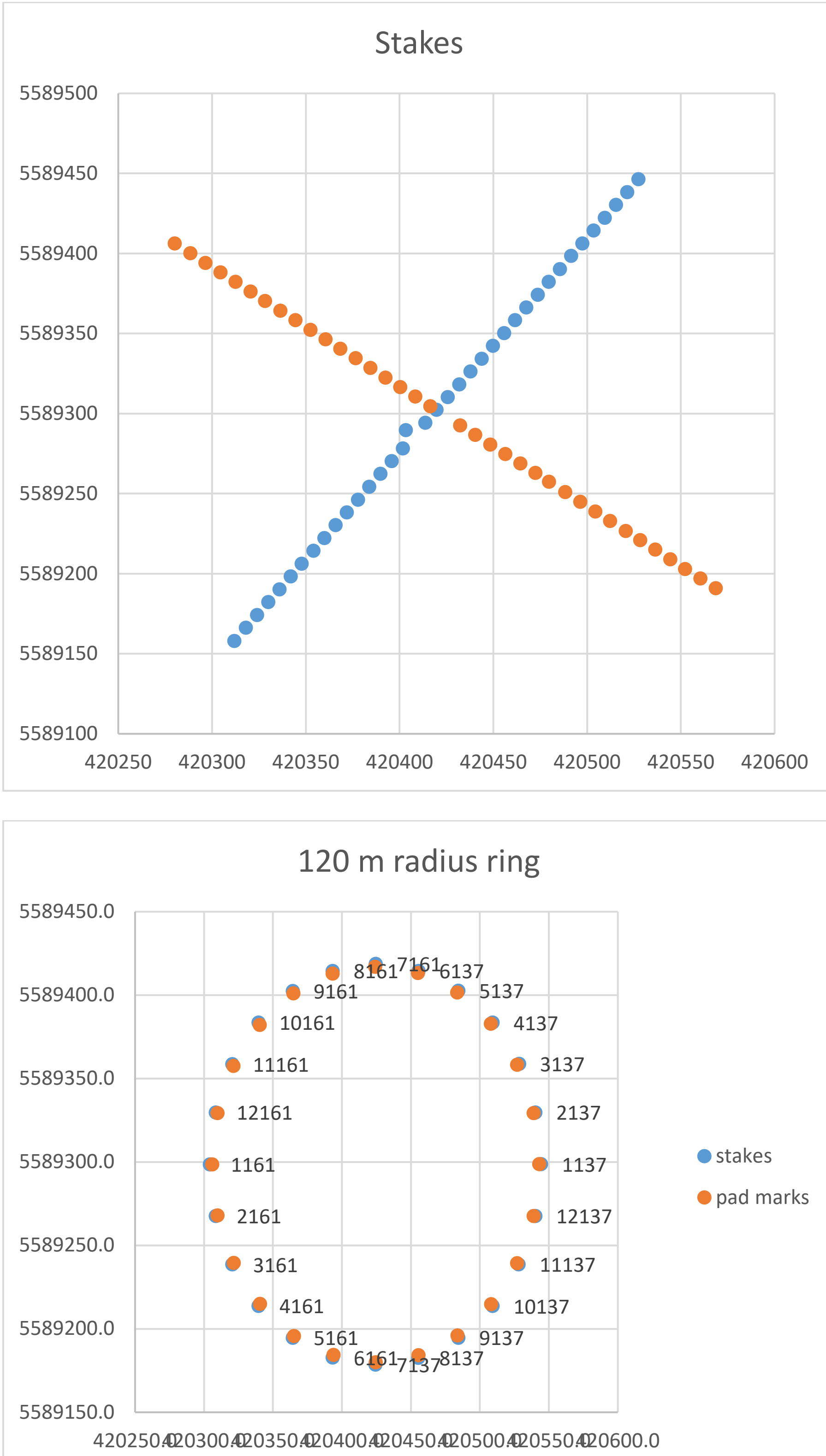


FIG. 11. Top: the staked lines intersecting on the observation well for walk away VSP source locations. Bottom: the staked circle for walk around VSP source locations.

Knowing that the lath would not last long (especially if cows are brought back to graze on the land) a large nail was also pounded into the ground. These nails can be found using a pin finder. The final thing done to mark the lines was to tie markers to the barbed wire fence surrounding the observation well. These can be used to sight from the well to chain out the shot points.

All shot points were also surveyed using the differential GPS and a record has been made of their location.

## FUTURE WORK

On of Rachel Lauer's students Tom Wilson has approached CREWES for help in carrying out a seismic survey in Banff Nation Park. The goal is to carry out this survey in March of 2020. His description of the project follows:

"In Banff National Park nine thermal springs occur in a linear trend along the Sulphur Mountain Thrust (SMT) fault zone, which provides a high permeability pathway for hot fluids to migrate to the Earth's surface from kilometer's below the ground and discharge from the springs. In recent years the highest elevation hot springs have experienced perennial flow stoppages over the late winter to spring months, threatening critical habitat zones and causing operational interruption to a spring fed swimming pool, which is a major tourist attraction for the region. A 3km reflection seismic line transecting, and perpendicular to, the fault zone allows to image the SMT up to a kilometer beneath the surface. The interpreted seismic section will provide spatial constraints on the SMT geometry at depth, and inform numerical models of fluid and heat through the fault zone. The produced models will be used to forecast future spring flow behavior."

There will also be tests using the repeatable VSP.

There are some early discussions of combining the geophysics and hydrogeology field schools next year. This will once again happen at CaMI.FRS.

Having proven to be an area with good data there are already discussions of returning the field school to this location in the future. There are also talks of using more geoscientific methods such as gravity measurements.

## ACKNOWLEDGMENTS

Field work is only possible when many people collaborate on the projects. The authers would like to thank the Seismic Group for the use of the acquisition equipment, CaMI for the use of the field research site, CREWES researchers and students; and the students of the University of Calgary undergraduate field school.

The authors would also like to thank the sponsors of the CREWES project as well as NSERC und the grant CRDPJ 461179-13 for making this fieldwork possible.


FIG. 12. Members of CREWES and the Department of Geoscience troubleshooting at the geophysics field schoo.

## REFERENCES

Macquet, Marie, Lawton, Don C., 2019, Ambient noise correlation study at the CaMI Field Research Station, Newell County, Alberta, Canada, **This volume.**

Innanen, Kris, Lawton, Don C., Hall, Kevin W., Bertram, Malcolm, Bertram, Kevin L., 2019, Detection of transient time lapse seismic signatures associated with $CO_2$ injection, **This volume.**