2021 CREWES field work

Kevin L. Bertram, Kevin Hall, Malcolm Bertram, Rachel Lauer, Kris Innanen

ABSTRACT

This year has seen a return to some of the normal operations of CREWES in the field. The ability to acquire field data provides CREWES a great advantage by providing the opportunity to test theories using actual seismic data.

Field acquisition projects that were carried out in 2021 include: a) a VSP survey carried out at the CaMI.FRS; b) a thumper test using the Seismic Group's nitrogen spring thumper trailer and a truck mounted thumper from Explor; c) testing of the CREWES downhole tool; d) the 2021 GOPH549 undergraduate field school; e) timelapse during CO_2 injection at CaMI.FRS.

INTRODUCTION

The first project took place in March of 2021 and involved a walkaway/walkaround VSP centred on the observation well at the CaMI.FRS. This survey used the same

The second project took place in April and involved testing thumpers as well as the three-component downhole geophone at the Priddis test site in the field west of the Rothney Astrophysical Observatory.

The third project saw a return to the Priddis test site in July. This was to test the Mount Sopris downhole tool belonging to CREWES as it hadn't been used in a few years. There was the possibility that this equipment could be used for testing later in the year and it needed to be ensured that it was still in working order. CREWES members also needed a refresher in how the tool is operated.

In August CREWES once again aided the Department of Geoscience with their geophysics undergraduate field school. This was a smaller operation than in year's past as the seismic reflection was suspended for this 2021.

The final project carried out before the 2021 CREWES Sponsors' Meeting of 2021 was a timelapse during CO_2 injection followed by a VSP at the CaMI.FRS.

EQUIPMENT

The equipment that was primarily used in the field for data acquisition this year include the Aries cabled recording system. This system has reached end of life, but for many years it was the industry standard for seismic reflection recording. The system consists of a computer connected via cables to Remote Acquisition Modules, Figure 1. The RAMs record either eight (single component) or twenty four (three component) channels of data. The RAMs digitize this data and transmit it back to the computer.

FIG. 1. An Aries eight channel RAM.

The second most used recording system are the Geometric Geodes, Figure 2. These are nodes that are capable of recording twenty four channels each. They are connected in series by their data cables and then send data back through a Network Interface Box. This NIB is connected to the ethernet port of any computer. So long as the computer has a Geometrics license it can run their software. More recently it is more common to find three of these nodes installed in an electrical box by the observation well at CaMI.FRS. They have been running continuous data acquisition for some time now.

FIG. 2. Three Geometric Geodes on display at Earth Science for Society in 2018.

Vertical Seismic Profiles are typically recorded using a Geostuff tool, Figure 3. This is a single three component geophone that is attached to a cable that is lowered down a well or test hole. The output can be interfaced with either the Aries or Geode recording systems.

There is also a cable to connected it to standard geophone connectors for any system that may be present. The tool has an electrically operated clamp to hold it in place at the desired depth, Figure 4.

FIG. 3. The Geostuff downhole interface and control box. This one has been modified to use an Aries RAM battery to power the clamping mechanism.

FIG. 4. The bow spring clamp that holds the tool in place in the well/test hole.

The downhole tool is from Mount Sopris and is set up to run three different types of surveys, Figure 5. All three tools connect to a cable that is mounted on an electrically operated winch. The winch system does provide feedback on how deep the cable has gone and can also automatically sample as the tools move up and down the well or test hole. The first probe measures the natural gamma radiation that occurs in rock formations crossed by a borehole. The second probe is a sonic logging tool and as such include both a source and receivers. The final tool is a spontaneous potential tool measuring resistivity between an electrode in the well and one planted in the ground at the surface.

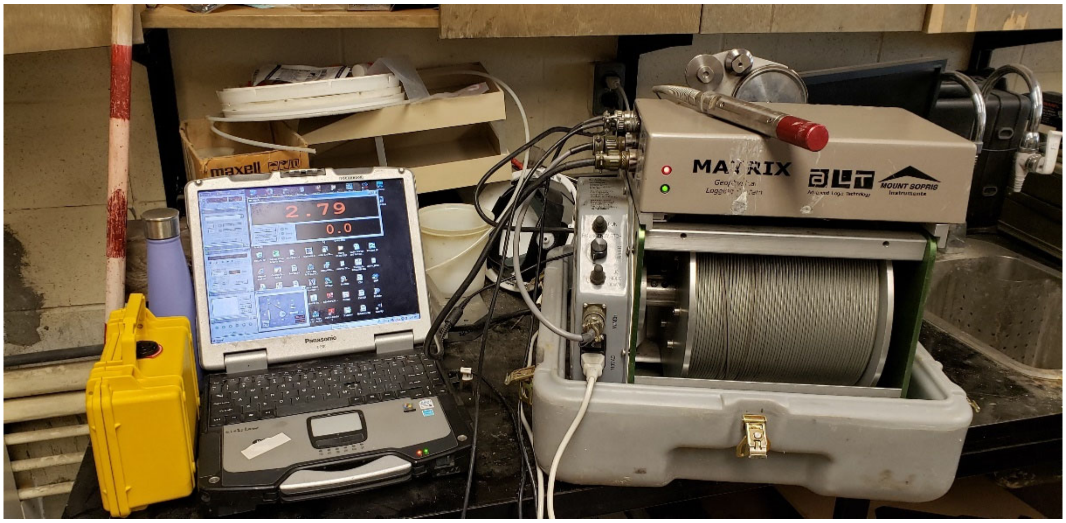

FIG. 5. The Mount Sopris downhole tool with winch.

Sources used this past year include a simple hammer an plate with a trigger. This is what is typically used when the Geodes are used for a refraction survey. The next step up is a nitrogen spring thumper built for the Seismic Group a few years ago, Figure 6. This thumper has the ability to tilt the driving mast forty five degrees to either side. The thumper was only used in the vertical setup this year.

FIG. 6. The nitrogen spring shear wave capable thumper. Malcolm for scale.

The largest source used is an Industrial Vehicles International Envirovibe, Figure 7. This unit is smaller than most commercial vibes so it can be used in more populated areas, has a smaller environmental impact, and can be towed on a trailer by a regular, albeit heavy duty, truck.

FIG. 7. The Envirovibe vibrator truck.

WALKAWAY AND WALKAROUND VSP AT CAMI.FRS

Source locations for VSP surveys were "flagged" permanently in 2019 with the intention of easily repeating the survey at any time to acquire a 4D survey. The GPS location data for all these sources have been recorded into a file that can be referenced each time the survey needs to be carried out.

This survey consists of three source "lines". Line 13 starts to the north and east of the well and ends to the south and west of the well. Line 15 starts to the north and west of the well and ends to the south and east of the well. Line 41 is the walk around source locations and are fifteen degrees apart, Figure 8.

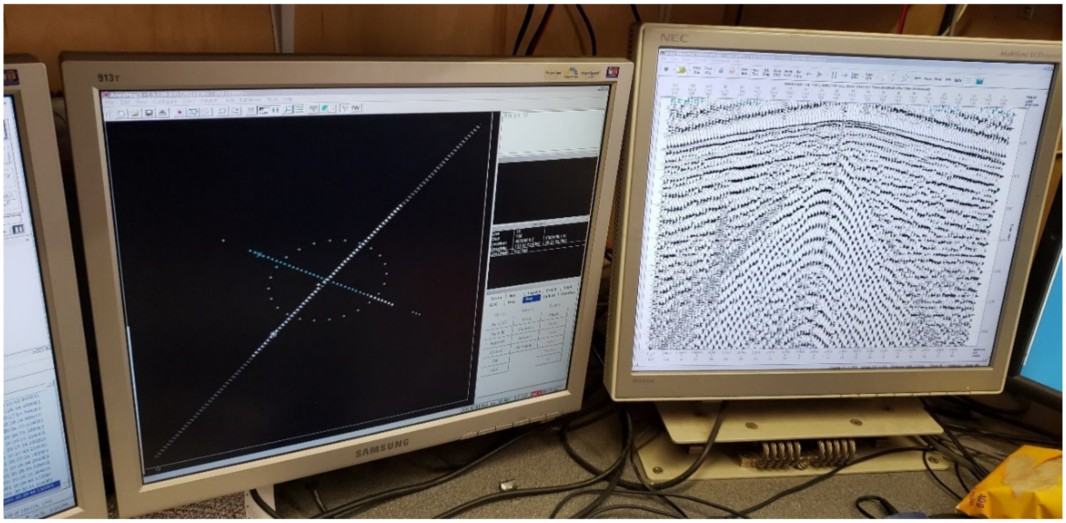

FIG. 8. The monitor on the left displays the sources as dots and receivers as double bars. The monitor on the right provides a typical example of the raw data in this region.

New this year is the ability to load this GPS file into a computer that travels in the vibroseis source and guides the operator to all the source location, Figure 9. This "stake-less" method of guidance saves time by not requiring that the GPS locations be physically marked using flags or stakes.

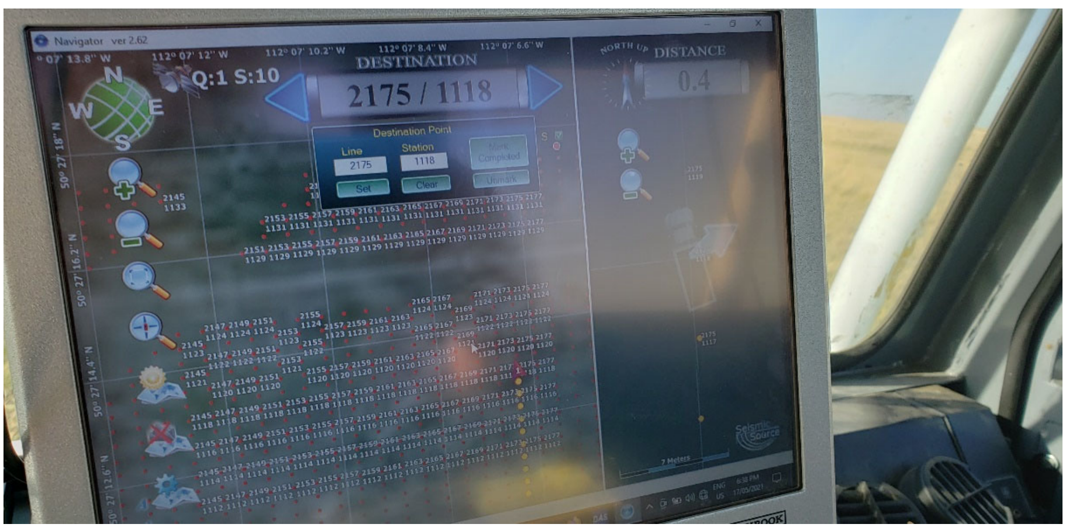

FIG. 9. An example of a map with GPS source points displayed on a laptop inside the cab of the vibe truck.

This survey had been done at the end of 2020 and the Aries equipment that was used to record the surface data had been subjected to the freeze and thaw that comes with winter in Southern Alberta. As such some of the equipment was buried in ice, Figure 10. Even though it had been left out for a few months everything came up green when connected to the recording system.

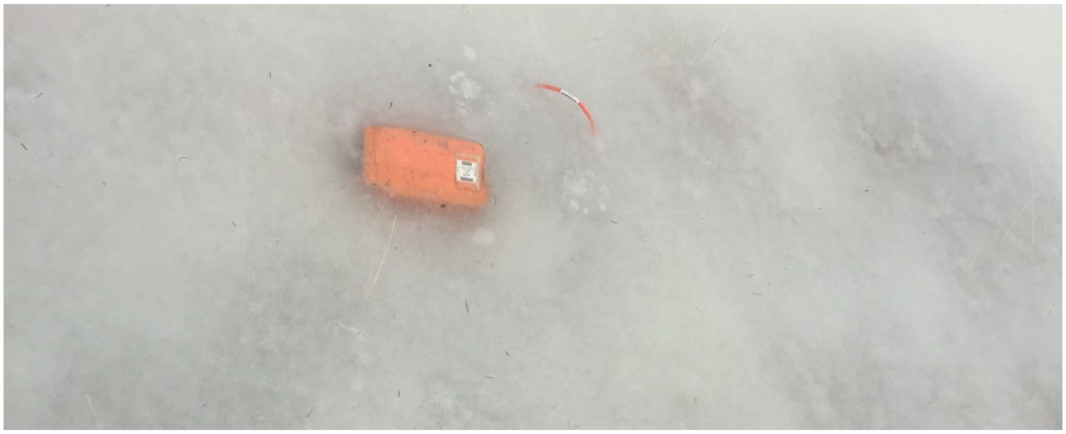

FIG. 10. An Aries battery buried under solid ice. The RAM itself cannot be seen under the ice. Fortunately, the battery still had enough power to finish the survey.

For this survey the Geode system was also connected. The Geodes sit in an electrical box near the well and are connected to all the three component geophones cemented around the well. They are installed in this box in an attempt to keep the 60Hz electrical noise that is present in the trailer on site from intruding on the data being recorded. A trigger was hardwired from the recording truck to one of the Geode nodes in the electrical box near the observation well. The Aries system was used to trigger the vibe and create the observer logs, which also include the GPS timing for each start of sweep.

We returned a few weeks earlier to pick up the gear once the ice had thawed.

THUMPER TESTING

This field work took place in April of 2021. The purpose of this trip was allow industry testing of a downhole tool and truck mounted thumper system. It was decided to take advantage of unlocking the well to use the Seismic Group's Geostuff downhole tool system and nitrogen spring thumper.

The well in question is the eastern most well in the south end of the field. This is one of the two most recently drilled wells in 2013 (Hall et. al. 2013). The other well drilled at the time has permanently installed phones on the outside of the casing as well as two loops of fibre. Unfortunately, both wells failed when they were being cemented into place and the accessible depth was unknown.

The western well has a depth of only tens of metres and was not used this day. The eastern well was expected to only have an accessible depth of sixty to seventy metres.

The first task carried out after removing the locking cap was to send the Geostuff 3C geophone tool down as far as possible. A chain was taped to the tool so the depth could easily be measured. Surprisingly the tool was able to reach its maximum depth (without the extension cable). The lowest depth that was used this day was 95m from top of well. The top of the well extends above the surface by approximately a metre, Figure 11.

FIG. 11. The top of the eastern test well at the Rothney Astrophysical Observatory field. The Geostuff cable is clamped using to pieces of wood hinged together and held tight with a c-clamp. The Geostuff box is in the top left of the picture.

The output from the Geostuff system was broken out into three geophone connectors (V, H1, and H2). These were connected to the first three inputs of a Geode node, Figure 12. The fourth was connected to a single component geophone located next to the well on the surface.

FIG. 12. The Geode node that the downhole geophone is connected to in front of a spare Geode.

The first source that was used was a hammer and plate. After sorting out some triggering issues the decision was made to use the more powerful nitrogen spring thumper. The thumper hasn't been run in some time, so it was given an once over before heading to the field. Its engine fired right away and everything appeared to be in working order.

A problem with the control switches did present itself in the form of the switches sticking a bit. These will be replaced.

Stacks of four thumps were done from the depth of ninety five metres up to five metres below the top of the well in ten metre levels. The well was filled with water from about six metres below the top of the well.

Once this was complete the other thumper was on site, Figure 13, so the decision was made to lower the tool back down to a depth of twenty five metres and compare the sources with a stack of four thumps from each. Upon completion of this test the Geostuff tool was removed from the well and the tool being tested by Explor was lowered into the well.

FIG. 13. The thumper brought out for testing.

DOWNHOLE TOOL TEST

The downhole tool test took place in the same well as the previous thumper test. The Mount Sopris tools required 110Vac and the generator that was intended to be used developed a fuel leak. At the last minute the decision was made to bring the recorder truck as well and use the diesel generator mounted on it. The rest of the equipment was placed in the back of a pickup truck, Figure 14.

FIG. 14. The Mount Sopris equipment mounted on the back of a pickup truck. The winch cable also has the electrical connections built in and can be seen going down the test hole via a wheel to avoid the sharp edge of the well casing.

The first tool that was tested was the gamma logging tool. It appeared to work at first, but then stopped providing data before it was loaded into the well. At this point the computer was rebooted and some lingering Windows updates decided to install themselves.

At this point it was decided to switch to the sonic logging tool. The main reason for this is that the sonic log tool provides a secondary method of determining if it was working. In this case when the tool is switched on it can be heard making a clicking noise, Figure 15. Once it was confirmed to be working the tool was lowered into the well and a sonic log was completed, Figure 16.

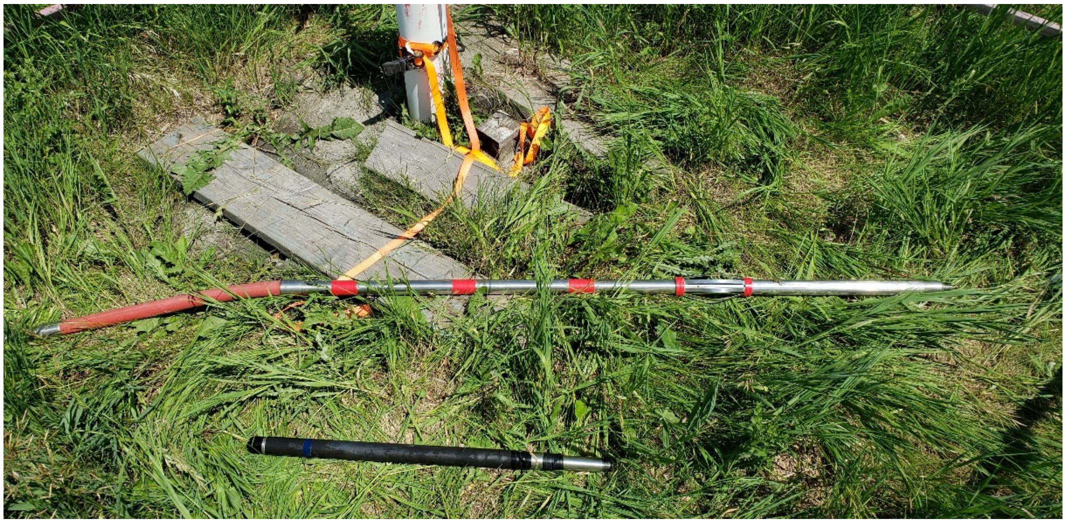

FIG. 15. The sonic logging tool. Each of the red markings on the silver shaft represent one of the receivers.

FIG. 16. Live data display on the screen while the sonic too was in the well.

The sonic logging tool was then powered down and removed from the well. The gamma logging tool was then reattached and sent down the well. A test was done where the gamma log was run twice, once at a faster speed and once at a slower speed. As predicted the slower speed yielded more detailed results. There were changed in the data at seventeen and twenty eight metres below the surface, Figure 17.

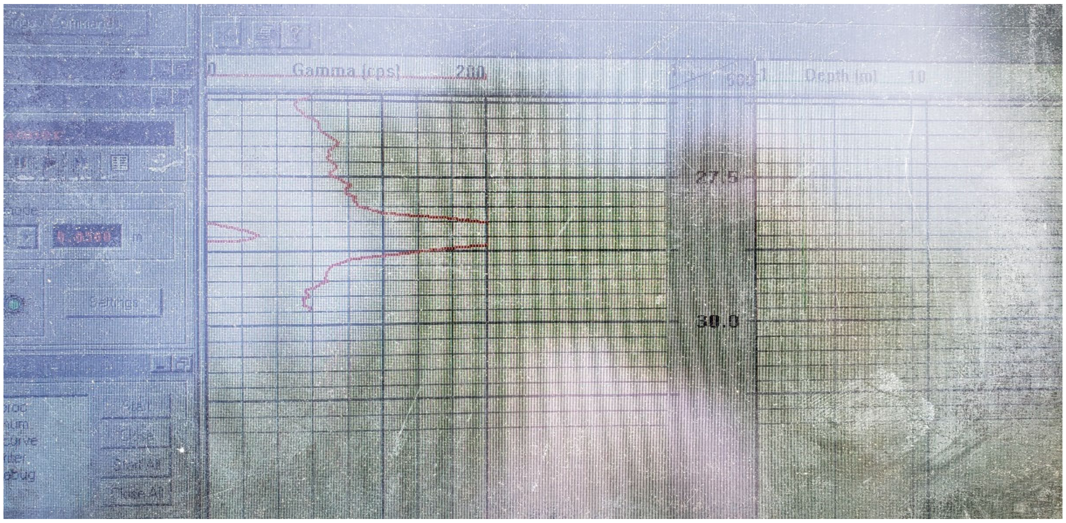

FIG. 17. The data from the gamma tool showing a spike at approximately twenty eight metres below the surface.

The spontaneous potential tool was next. This required the SP electrode to be attached to the cable on the winch and a grounding electrode in the soil on the surface, Figure 18. No real results were recorded using this tool as the well is incased in plastic which acts as an insulator. Resistance increase as the tool was winched up to the surface. It is also obvious where the top of the water table is by a sharp increase in resistance.

FIG. 18. The cable for the ground electrode can be seen over the side of the trucks box.

All the tools were used to a maximum depth of fifty metres.

FIELD SCHOOL

The University of Calgary usually runs a geophysics field school every summer. This class introduces geophysics students to data acquisition methods that are used by companies around the world. Unfortunately, the 2020 field school was unable to be conducted due to the restrictions on gatherings. This year saw a return to field school.

The field school was carried out at the Castle Mountain Resort located southwest of Pincher Creek in Alberta. Even though the field school returned this year it was a smaller operation than years prior. The seismic reflection portion was dropped this year.

This year the student too part in the following data acquisition activities:

- Seismic refraction. A short line of geophones were laid out and connected to the Geode recording system. A hammer and plate were used for the source.
- VSP survey. A three-component geophone was lowered into a well at various depths and connect to the Geode system. Again, a hammer and plate was the source used.
- GPS. The differential Global Positioning System was set up and used to acquire accurate locations for sources and receivers.
- ERT. An Electrical Resistive Tomography survey was set up and run by the students.
- GPR. A Ground Penetrating Radar survey was carried out. However, past surveys have shown that there isn't much to be seen using the GPR cart in this location. As a result targets were built to stand above ground and the GPR was run on its side to find them.

TIMELAPSE DURING CO_2 INJECTION AND VSP

The final field acquisition survey was a repeat of an experiment carried out in 2019 (Innanen et. al. 2019). This survey required that the source, in this case the Envirovibe remain in the exact same spot for every single shot. As a result the vibe was parked on this GPS marked spot and stayed there for the entire survey with the pad on the ground.

The goal of this survey was to gather data on the effects of CO_2 injection on the subsurface during VSP acquisition, Figure 19.

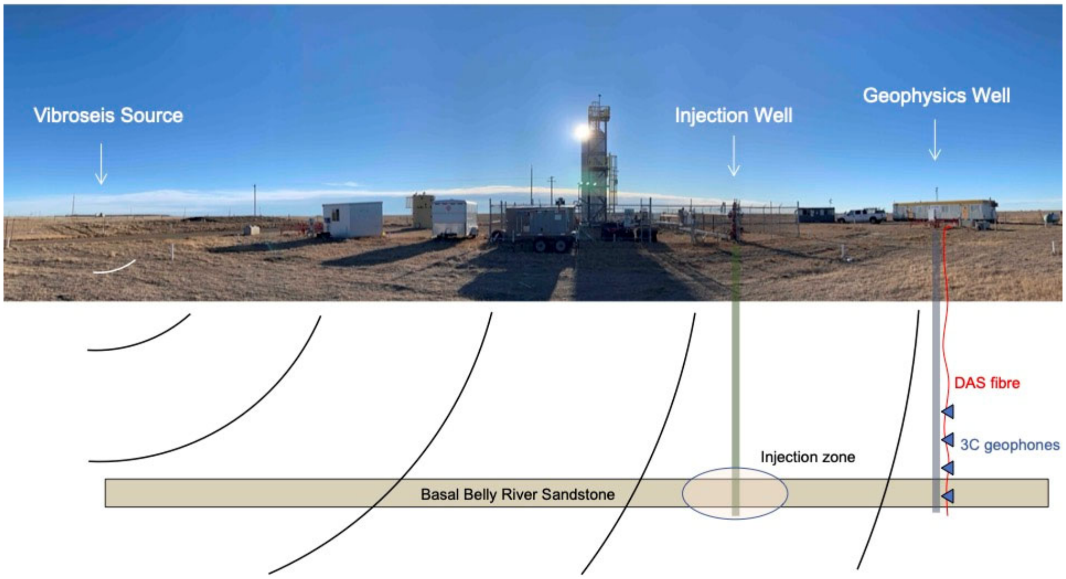

FIG. 19. An overview of the parametres for the experiment.

Data was acquired using the Geodes connected to the permanently installed three component geophones around the observation well. There is also a new DAS acquisition system that CREWES has partial ownership of. This trip also provided the opportunity connect it to the fibre installed along the trench and down the test holes at CaMI.FRS.

In this case the vibe had to be triggered by an encoder in the trailer at on site. This was connected to the trigger for the Geodes, DAS, and the Verif-i GPS synchronizer. The Verif-i output the GPS time of each start of sweep to the serial port of the Geode laptop computer, which was then used to create the observer notes, Figure 20.

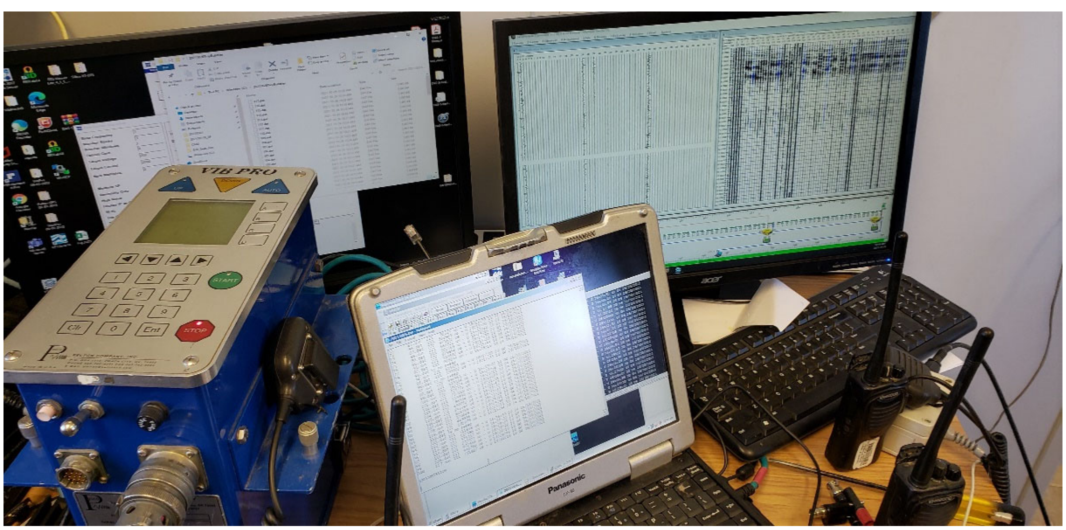

FIG. 20. The setup in the trailer with the Geode downhole data on the screens in the back. The observer notes and GPS timing is handled by the laptop in the front. The encoder running the decoder in the vibe is the blue box on the left.

The first day was eaten up by getting all the equipment set up and communicating properly. The next three days were used to record hundreds of sweeps at the same spot while CO_2 injection was started, stopped, and as the injection site relaxed. Unfortunately, there was an issue with the injections system and not as much CO_2 was injected as was desired. Although none of the DAS data has yet been processed it is good to know that individual sweeps can be seen on the live noise monitor, Figure 21. The data from the Geodes has already been looked at, Figure 22.

FIG. 21. How a sweep appears on the DAS system noise monitor.

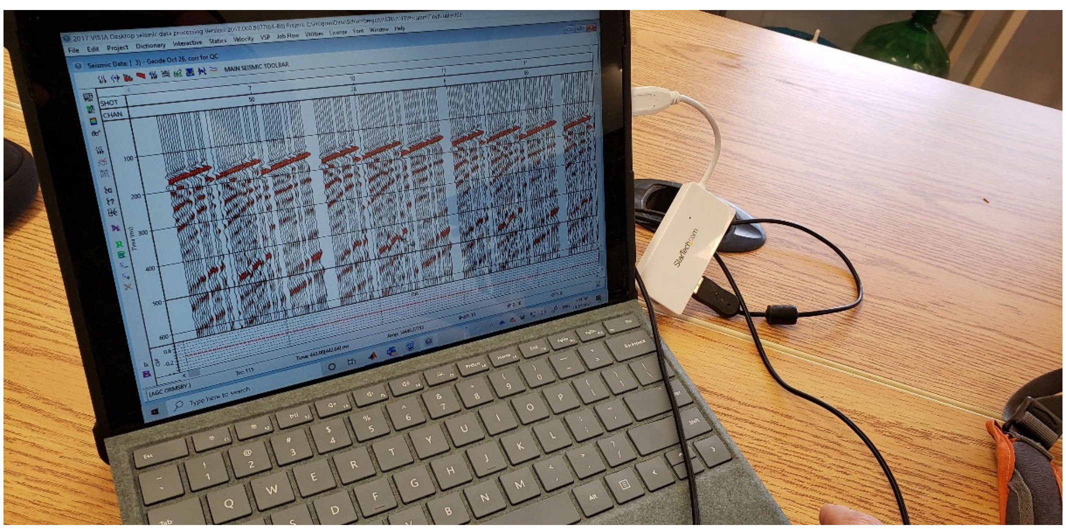

FIG. 22. Some of the data recorded in the well during the experiment, after stacking and correlating with the pilot sweep from the vibe.

The morning of the last day was used to repeat the VSP survey that was carried out in March. However, this time there were no surface receivers recording, except for the fibre in the trench (Line 13). Once again, the vibe was started using the encoder in the trailer and the Verif-i for timing.

FUTURE WORK

Members of CREWES are always eager to perform field work. The VSP survey at the CaMI.FRS is planned to be carried out many times over in the future. There are also plans to return to acquire more sets of data for the timelapse during CO_2 injection early in 2022.

It is also hoped that the GOPH549 field school next year will see the return of the seismic reflection portion of student data acquisition.

ACKNOWLEDGEMENTS

The ability to perform field acquisition surveys requires the collaboration of many people and groups. The authors would like to thank the Seismic Group for the use of acquisition equipment. Data from the CaMI.FRS was acquired through a collaboration with the Containment and Monitoring Institute, Carbon Management Canada.

The authors also thank thank the sponsors of CREWES for continued support. This work was funded by CREWES industrial sponsors and NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 543578-19.

REFERENCES

Hall, K. W., Bertram, K. L., Bertram, M. B., Gallant, E. V., Margrave, G. F., and Lawton, D. C., 2013, Installation of new observation wells at the Priddis Geophysical Observatory: CREWES Research Report, **25**.

Innanen, K. A. H., Lawton, D. C., Hall, K. W., Bertram, M. B., and Bertram, K. L., 2019, Detection of transient time lapse seismic signatures associated with CO_2 injection: CREWES Research Report, **31**.