Field school 2022, exposing the geoscientists of tomorrow to field acquisition methods

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ABSTRACT

This is the second in person field school since 2020. Although there was a field school last year, it was missing the reflections survey that had been traditionally carried out. This year saw the return of this. However, participation numbers are still lower than in years past and this year's field school was shorter than most. The University of Calgary's geophysics field school is often one of the first time that students have the opportunity to witness and operate the equipment used for collecting data that that have been, or will be, studying. This provides a vital link in the thought process as to why certain raw data may appear as it does. And it grants an understanding that data collection in the outside environment doesn't always conform to simulated data often used for teaching processing and interpolation methods. All acquisition was performed at the Carbon Management Canada Newell County Facility (formerly the CaMI Field Research Station) near the town of Brooks, Alberta.

INTRODUCTION

Geophysics field school in 2022 took place from Friday August 18th through to Thursday August 25th. First all the students were taken through a safety orientation upon arriving. Each day in the field was a full day of laying out the equipment, acquiring data, and then packing the equipment up again.

The day after the students arrived the actual education part of field school began. It started with a focus on the vertical seismic profile of the observation well. Both three component geophones and fibre optic cable, for distributed acoustic sensing, are permanently installed around the casing of this well. The afternoon was then spent laying out the equipment for the reflection seismic.

The third day in the field concentrated on reflection seismic. The students were broken up into groups with one group finishing the layout and the other running the instruments and acquiring data.

Day four saw the students that had done layout the day before running the instruments and acquiring data. Those students who were not involved with acquiring data started layout of the refraction equipment. Refraction acquisition and data interpretation took place the rest of the day.

Day five finished off the refraction survey and then layout of the electrical resistivity tomography equipment was performed.

Day six was the last day of field data acquisition. The ERT survey was completed and all acquisition equipment was packed up for transport back to Calgary.

Day seven was a classroom day where the students finished their written assignments and organized the data they collected.

On the final day the students had their final exam in the morning. Everyone returned to Calgary that afternoon.

VERTICLE SEISMIC PROFILE

The members of CREWES who staffed field school this year had already been in the filed almost a week performing acquisition for a major research project (Innanen et. al. 2022). This research project mainly revolved around data acquired using the observation well. As a result, the acquisition equipment was already set up and running to record data from the permanently installed instruments in the well, Figure 1.

FIG. 1. Students and instructors standing by the observation well.

The well has permanently installed three component geophones cemented on the outside of the casing. The geophones are wired to a junction box at the surface. This junction box has three Geometrics Geodes recording units connected to the geophones. Each box brings in one of the three components for each geophone (vertical, inline, and crossline). The three Geodes are connected together using ethernet cable. This cable is then run into the nearby Atco trailer. Here a fourth geode is connected. This fourth Geode is used for triggering and correlation with the seismic source.

The source used for this acquisition is the Industrial Vehicles International Envirovibe, Figure 2. The vibe ran a few sweeps and the students were able to observe the data recorded by the geophones.

FIG. 2. The IVI Envirovibe.

The well also has fibre optic cable installed around the casing. This cable was connected to DAS unit and as a result the students were able to observe raw data on this system as well.

REFLECTION SEISMIC

The reflection seismic started with layout. There is a buried fibre optic cable as a sensor along a trench. This is often used as a reference for laying out surface sensors. This is referred to as Line 13. The first task was to determine receiver positions by using known reference points and a chain. The three component phones have a diameter of a couple of inches. As such, once the receiver points were marked an auger was used to bore a hole in the surface for a geophone to be planted. Geophones were orientated with the inline component pointing to the beginning of line (BOL) located at the north end of the trench. The receiver spacing was ten metres. The entire line was just over one kilometre in length.

After the geophones were planted in the ground it is essential that their precise location be known. For this a differential Global Positioning Syster (GPS) is used. GPS is widely available these days through smart phones, automotive navigational system, and even watches. However, these systems have an accuracy of metres and will typically assume that the system is on the nearest path/road. For increase accuracy the differential system uses two GPS units. The first is the base station that is set up over a known location. This location can be a survey monument or simply a location where the GPS can sit and take many measurements, which are then averaged. Once the base station is set it takes the location it calculates from the GPS satellites and compares it to its known location. This comparison yields the assumed error from the satellite calculated location.

The base station then transmits this error to the other GPS unit, the rover, over a built in radio. So long as the rover and the base station are using the same set of satellites to calculate their positions the error can be assumed to be the same for both the base station and the rover. When the rover is used to store a position it applies this error to the recorded data. This increases the accuracy of the recorded position to centimetres. The students used the differential GPS system to store the location data of each geophone that was planted, Figure 3.

FIG. 3. Students using the differential GPS to record the location of each geophone.

The system used to record the geophone data is an ARAM (now Inova) Aries seismic system. This system consists of Remote Acquisition Modules (RAMs) that digitize the analogue signals from the geophones, Figure 4. This digital data is then transmitted to a central computer called the Seismic Processing Module Lite (SPML) through a line tap.

FIG. 4. A twenty four channel three component RAM and a line tap. The line tap is connected to the blue cable. Also visible are two batteries (orange boxes) and a geophone planting pole.

The software on the SPML is used to determine how they RAMs are deployed and connected. The system can also test the equipment to ensure that all communications and receivers are working withing expected parametres. Once everything is connected and tested the system is used to start a source at the exact time it starts to record data.

The source used for the reflection acquisition is again the IVI Envirovibe. For this survey it ran a sixteen second sweep starting at ten hertz and ending at 150 hertz. 250ms cosine tapers were used at either end of the sweep. At each shot point the vibe ran four sweeps. The Aries system was recording three second records. At each shot point the system recorded four nineteen second long sweeps (sweep time plus listen time). These four sweeps are then stacked together. The stacking is a method of increasing signal to noise by stacking out the random noise (noise present at one location on one sweep). This stacked record is correlated with the sweep provided by the vibe controller electronics which results in a three second sweep.

The reflections seismic data is known to be fairly good providing the students with raw data that can have some initial interpretations done on it. The raw records are printed out and often taped to the door of the recording truck, Figure 5. The students are then cycled out of the recorder to discuss the record and identify areas of interest.

FIG. 5. A field school student discussing the raw seismic record recently acquired. The vertical components are displayed on the of the paper taped to the door. The first breaks, air blast, and a reflection can all be seen in this image.

Looking at a raw seismic record can prove a little challenging for those who haven't seen many (or any). The two most prominent features are the first breaks and the air blast, both of which often appear as straight lines. The first breaks start at the source location and typically has a few traces of direct arrivals and then a crossover point near the source where the first breaks become refracted arrivals. This occurs because the surface in this area is unconsolidated and the speed of the source energy through it is slower than the media below it. The air blast is the other straight line which is travelling slower.

These raw seismic records are plotted with he x-axis being trace number, and the y-axis being time increasing from top to bottom. Knowing that the trace spacing is ten metres it is trivial to calculate the velocity of the first breaks and air blast. This is often a “light bulb” moment when the students realize that the slower moving straight line has a velocity of around 340m/s.

In this area there is a reflection that can be seen on the records. The students were asked to use the first break velocity to determine the approximate depth of the reflection. An error in this calculation that is very commonly seen is that the students tend to forget that this is a reflected arrival, not a direct arrival. The energy from the source isn’t arriving directly at the receivers, but heading down to the reflected media and then back up.

REFRACTION SEISMIC

The refraction survey uses the same Geometric Geodes as the VSP survey. However, single component (vertical) geophones are used. Each Geode can record data from twenty four geophones. Because the refraction survey’s area of interest is primarily the first breaks the geophone are laid out with a two metre spacing for higher resolution. Three Geodes were laid out for a total of seventy two receivers, Figure 6.

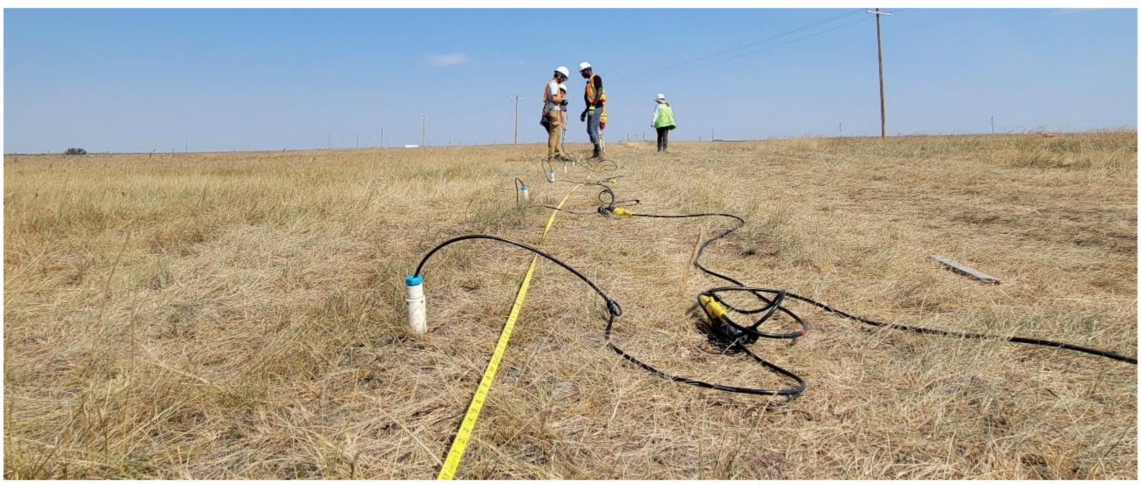

FIG. 6. Single component geophones laid out and connected to the Geode system for refraction seismic.

A hammer and plate were used as a source. The students took turns swinging the hammer. Once again data could be stacked to increase signal to noise. Since the signal is weaker than the vibe (no offence to students!) a stack of ten hammer hits were used for each record, Figure 7.

FIG. 7. Students interpreting data recorded on the Geode system on a laptop. Shade is non existent in this area so a tent was used to keep the sun off the students and laptop.

The refraction records once again were plotted with trach number on the x-axis and time on the y-axis, Figure 8. Once again the first breaks nearest the source are direct arrivals with a slower velocity. This time, however, there is more detail in the first breaks because of the higher density spacing. Two more sections of the first breaks present as straight lines. One of these had a velocity of around 1,500m/s. This is the seismic velocity through water and the students were able to use this to determine that the water table was approximately twelve metres below the surface. The second straight line of first breaks were the same as the refracted arrival first breaks seen on the reflection data. This is the bedrock. The students were able to use the refraction data to determine that the bedrock was approximately thirty metres below the surface.

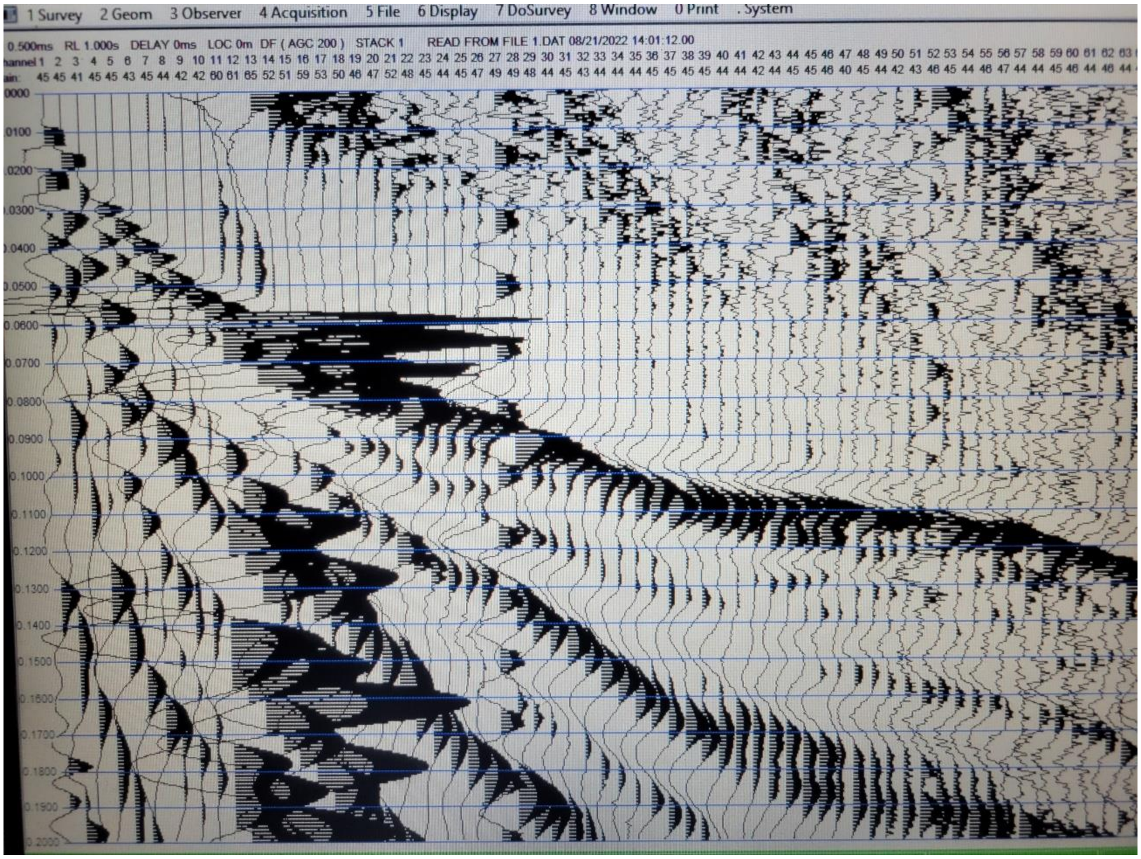

FIG. 9. A refraction seismic record created by the students in the field.

ELECTRICAL RESISTIVITY TOMOGRAPHY

The students planned, set up, and ran an electrical resistivity tomography (ERT) survey. The objectives of the ERT survey were to image bedrock and the water table, to compare the interpreted depths with seismic data, and to calculate the depth of investigation (DOI) of the survey after Oldenburg and Li (1999). The students decided to use an electrode spacing of 5 m to reach their estimated depths of bedrock, and to overlay the ERT line with the refraction seismic line and the northeastern section of the reflection seismic line to accomplish the first and second objectives, respectively.

The ERT line extended from near the classroom trailer to 800 m northeast, and the data was collected using the ABEM Terrameter. The students learned how to troubleshoot negative resistivity readings on an ERT line, and how errors affect the data interpretation and the DOI. They also learned how to process, invert, and interpret the data using RES2DINV (Loke, 2018), and they wrote their own code to visualize the inversion results.

The resulting earth model included resistivities ranging from < 1 Ωm to 50 Ωm, Figure 8. A layer of higher resistivity was located from the base of the earth model at 70 m depth to 30 m depth, which was overlain by a layer of low resistivity from 30 m depth to a few meters below the ground surface. The top few meters of the earth model consisted of higher resistivities likely due to evapotranspiration, and the change in resistivity at 30 m was interpreted as the top of bedrock. The DOI was calculated using the methods of Oldenburg and Li (1999), and it identified an area of low data sensitivity at 55 m to 95 m distance and 15 m to 30 m depth. This area was also the location of negative measurements recorded in the field that were removed from the dataset prior to inversion. It provided an excellent opportunity to illustrate the sensitivity of the earth model to collected data, and whether the earth model is an accurate approximation of the actual geology.

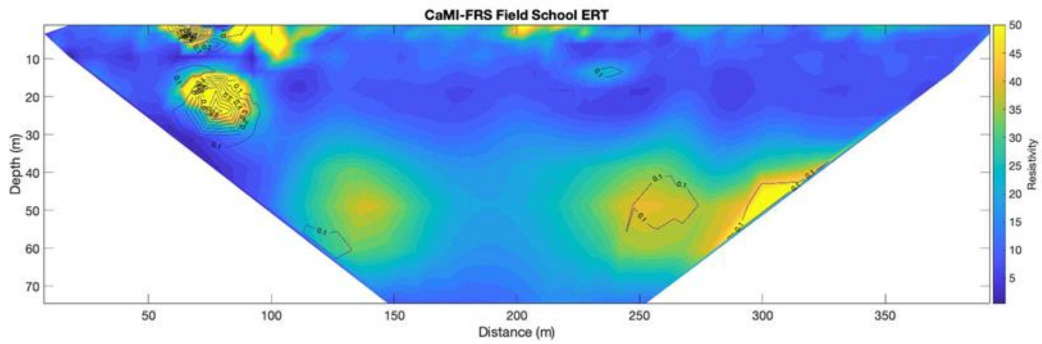

FIG. 8. The CaMI-FRS Field School ERT earth model with DOI values overlain on the resistivity contours. DOI values greater than 0.1-0.2 indicated where the model was the least sensitive to the field data and identified areas should not be included in the interpretation.

FUTURE WORK

Those members of CREWES who are involved with the geophysics field school always look forward to the next one. There are many decades worth of experience shared with these members and the opportunity to pass knowledge from this experience to the geoscientists of the future is a major advantage of the U of C GOPH549 field school.

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