# Seismic acquisition projects 2010

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## ABSTRACT

Acquisition projects since the CREWES meeting in November 2009 include: a) a VSP test of a new downhole tool based on the Vectorseis MEMs sensor at the Priddis test site in the existing 130m deep well; b) a 3C-3D survey over the southern field at Priddis to further investigate locations for the planned injection well site for CO2 sequestration; c) a test on the University of Calgary campus of the AWD thumper to quantify output versus band tension; d) the 2010 GOPH549 undergraduate Field School project which shot a 3C 2D line along a road allowance on the southern boundary of the Priddis test site, continuing west for a total length of 2.5 km.

## INTRODUCTION

The first project was carried out in December 2009 and involved a test of a new downhole tool based on the Vectorseis MEMs three component sensor. This was undertaken along with two short orthogonal lines of surface 3C geophones meeting at the well. This survey was to test the new downhole array as well as attempt to refine knowledge of the shallow aquifers which the well intercepted. The work was carried out in conjunction with High-Definition Seismic Corporation who supplied the tool and Geokinetics who supplied the Vectorseis sensors and the recorder. Sources used were the University of Calgary EnviroVibe, and the new thumper constructed by CREWES.

The second project was an extensive 3C 3D survey of the southern field at Priddis in May 2010. For this survey the Aries three component system was provided by Aram Rental Corporation. Seven lines of SM7 3C geophones were laid out east-west, and fifteen shot lines oriented north-south were shot using the University of Calgary EnviroVibe. Both geophone and shot spacing was 10m, with 50m between lines.

The thumper test was carried out on the west end of the University of Calgary campus and was intended to show the changes in output both in frequency and amplitude from changes in elastic belt tension on the accelerated weight drop unit constructed by the CREWES project in 2009.

The Geophysics Field School line was shot by the GOPH549 undergraduates and was designed to provide more information about the shallow structure beneath the Priddis test site, extending west to cross the surface expression of the east dipping sandstone layers on the east side of the triangle zone. This line was shot using the Aries three component recording system provided by Aram Rental Corporation. Geophone spacing was 10m and the University of Calgary EnviroVibe was again used as the source with a VP spacing of 10m.

## VECTORSEIS VSP TOOL TESTS

The Vectorseis VSP tool was developed by High-Definition Seismic Corporation for shallow high resolution VSP surveys. The system uses standard Vectorseis sensors and needs to be installed in a dry hole. Since the University of Calgary Priddis test site has a 130m well which could be pumped out, and there was an interest in trying to refine our knowledge of the shallow aquifers in the region for ground water studies, a joint project was conducted between High-Definition Seismic Corporation, Geokinetics and CREWES. The Vectorseis tool was installed in the well with a spacing of 2m between sensors, and two surface lines planted, one east-west, the other north-south with the intersection at the well head. The east-west line was connected as two lines with the sensor nearest the wellhead being the first trace on each. The University of Calgary EnviroVibe was used as a source, providing multi-azimuth locations at various offsets. A number of different sweeps were used, firstly 10-250Hz, then 2-15Hz, 10-25Hz, 15-35Hz, 25-50Hz, 40-70Hz, 60-105Hz, and 95-155Hz. The AWD thumper was also used as a source for this survey. The layout of the survey with the occupied source points is shown in Figure 1.

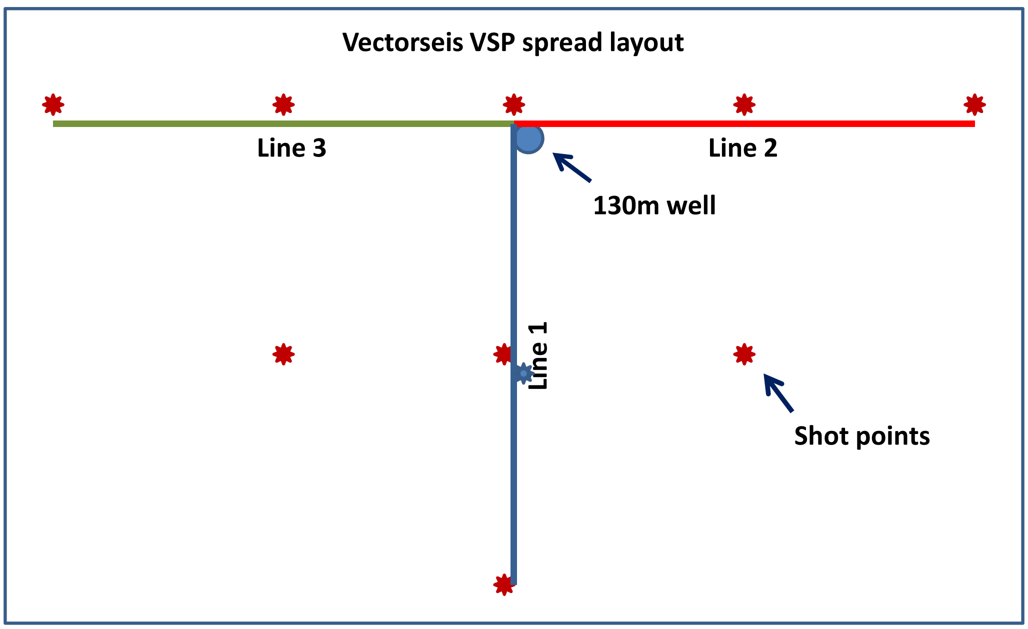


FIG 1. Layout of VSP survey December 2009

A gather from the survey is shown is Figure 2. This is the vertical component of the 3C sensors, with the three surface lines on the left side of the figure and the downhole array on the right. This gather is from a zero offset 10-250Hz sweep by the EnviroVibe. There are some issues with casing bonding in this well, giving some areas where coupling is poor and data loss occurs. Figure 3 shows a thumper shot at zero offset with a 10-15-80-100Hz filter applied.

The Vectorseis VSP tool proved to be a good high resolution system, since the whole well depth was recorded as a single spread with 2m spacing, providing the ability to record the entire depth with a single shot.

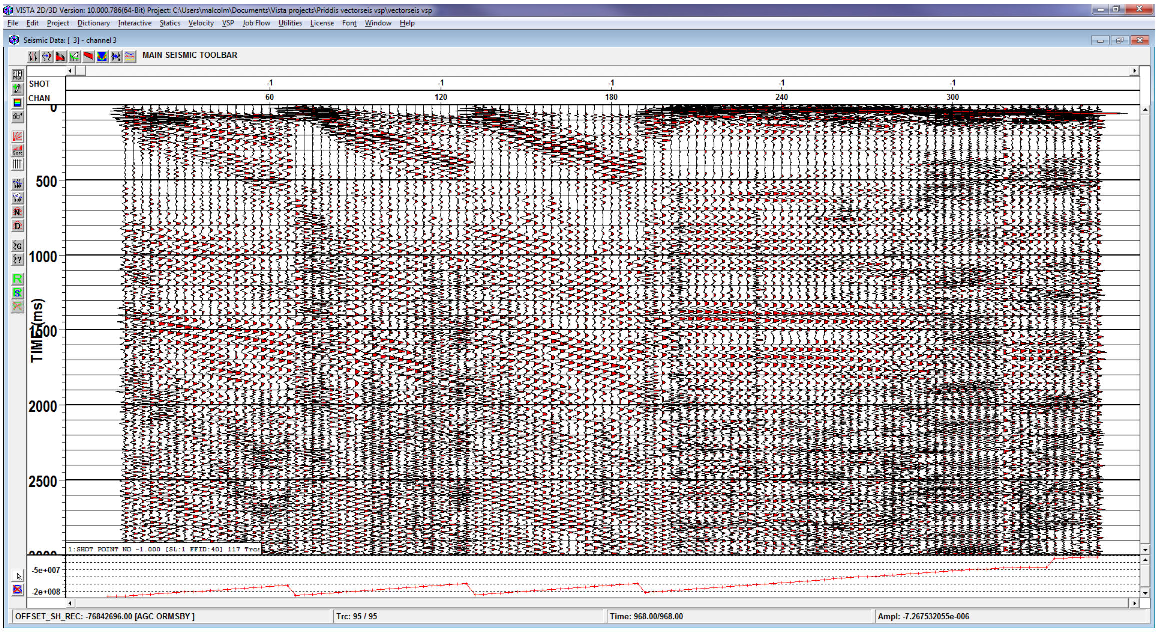

FIG 2. A correlated EnviroVibe gather from the VSP survey. The left half has the three surface lines, the right half is the downhole array. Filter of 10-15-80-100 applied.

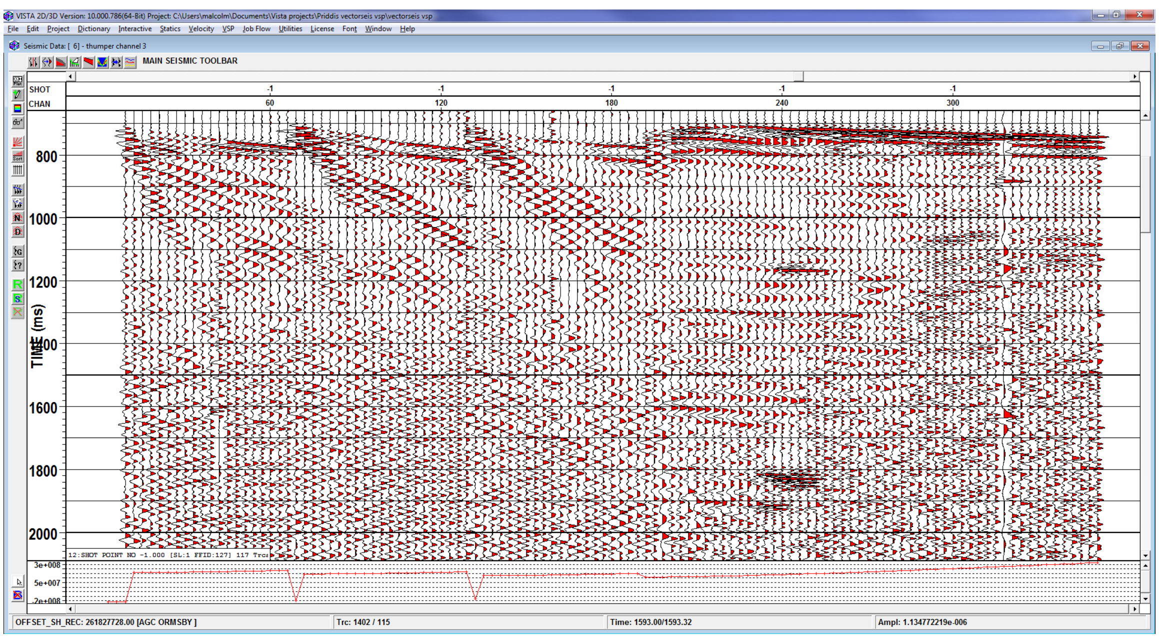

FIG 3. A thumper shot gather for zero offset. Filter of 10-15-80-100 applied.

## MAY 3C 3D SURVEY

This survey was designed to establish the preferred location for the injection well location for the planned CO2 test site at Priddis. The survey layout is shown in Figure 4. Geophone lines were east-west and shot lines north-south.

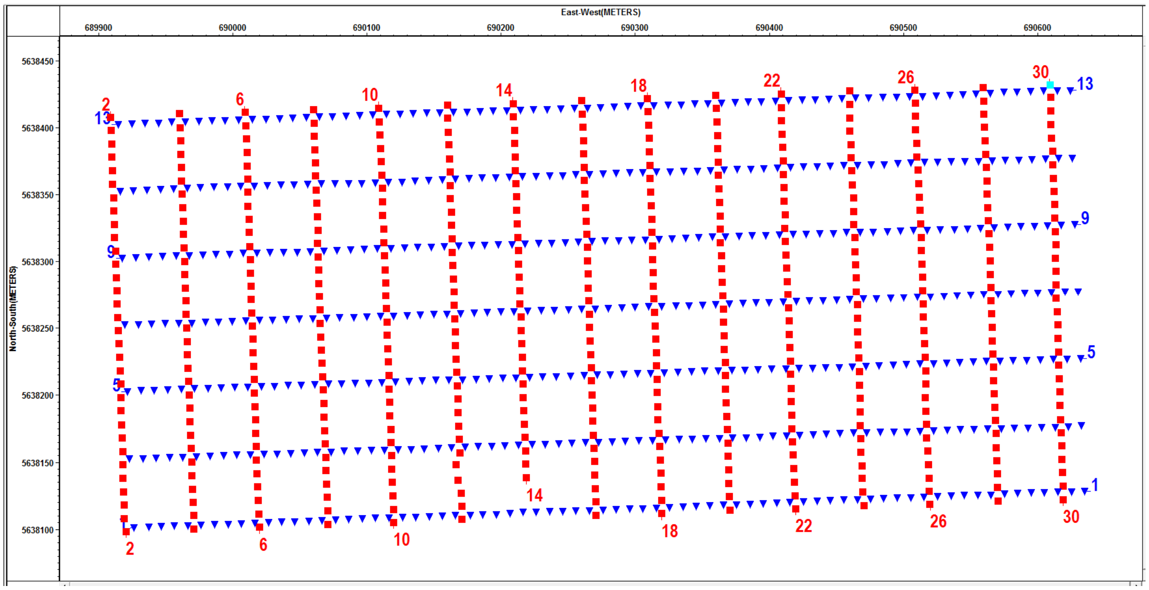


FIG 4. The layout for the May 2010 3C-2D survey. Receiver lines in blue, shot lines in red.

The spacing between both receiver lines and shot lines was 50m, with geophones and shots spaced at 10m on their respective lines. The receiver lines each had 72 3C Sensor SM7 geophones deployed. The geophones and 24 channel RAMs for the survey were provided by Aram Rental Corporation. The source for the survey was the University of Calgary EnviroVibe, with a sweep of 10 to 200Hz over 20 seconds; 4 sweeps per vibe point. Data was recorded on the University of Calgary SPMLite Aries recording system. The data from two receiver lines is shown on Figure 5. Data was of reasonable quality, with reflections visible to greater than 2 seconds.

A cube of the first second of processed data is shown in Figure 6, showing a number of horizons dipping east in the shallow section. At depth, the structure is horizontal, showing that this is the effect of the typical triangle zone wedging caused by thrusting from the west. These are interpreted to be sandstone horizons and some can be found outcropping to the west. Some samples were taken of one outcrop to establish porosity and permeability parameters. The 2010 Field School seismic line crosses some of the outcrops as shown later in this paper.

The converted wave data from this survey has not yet been completely processed, but is currently being worked on.

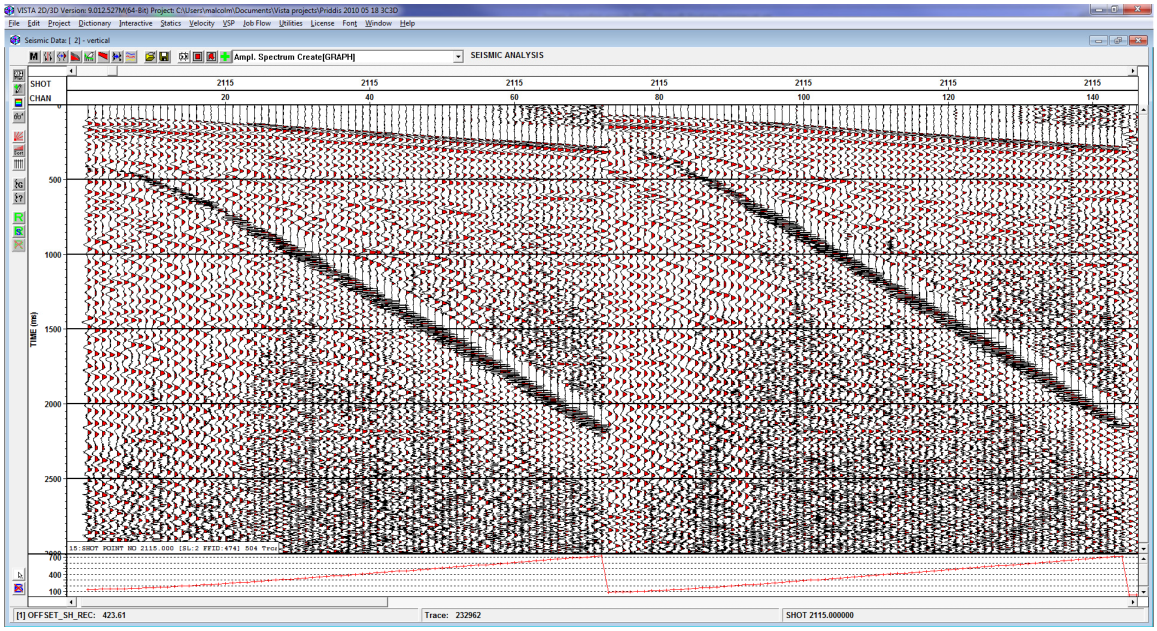


FIG 5. An example of the data quality fron the May 2010 3C 3D survey at Priddis. This show two receiver lines from the patch with no filtering applied.

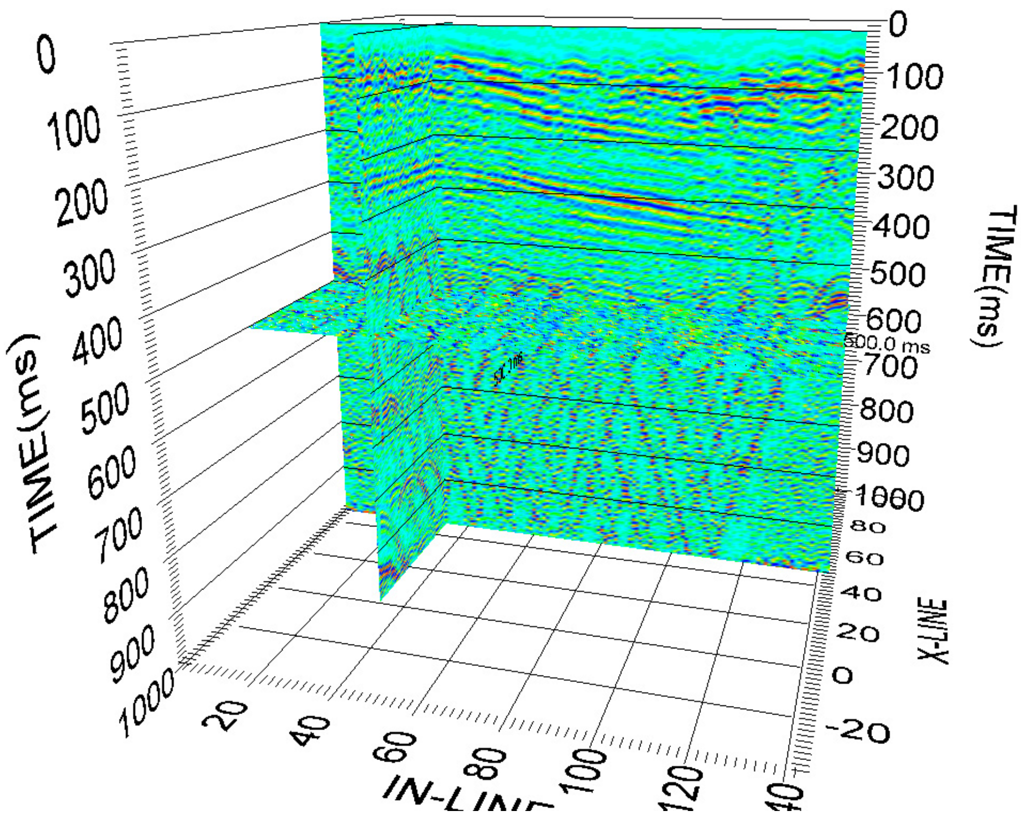


FIG 6. A chair display of the cube showing the shallow reflectors which outcrop to the west. North is in the X-line direction.

## THUMPER TESTS

To analyze the output from the new thumper which was constructed in 2009 by the CREWES project, a small survey was set up on the west section of the University of Calgary campus in August 2010. A spread of 80 geophones was set out at a spacing of 2m and the thumper positioned in the centre of this spread. A number of shots were recorded at different setting of tension on the elastic bands used to accelerate the hammer. A video camera was also deployed to attempt to measure the impact velocity of the hammer, but results from this were not conclusive. At the time this survey was done, the trigger system for the source was incomplete, so a manual start time on the recording instruments was utilized to capture the impacts. This turned out to be serendipitous as there is an event visible on the records which is the release of the hammer at the start of the drop. By the time difference between release and impact, a measure of the relative velocity for different tensions is possible. Figure 7 shows one record from this survey, with the release time evident at about 350 msec, and the impact on the base plate at about 550 msec.

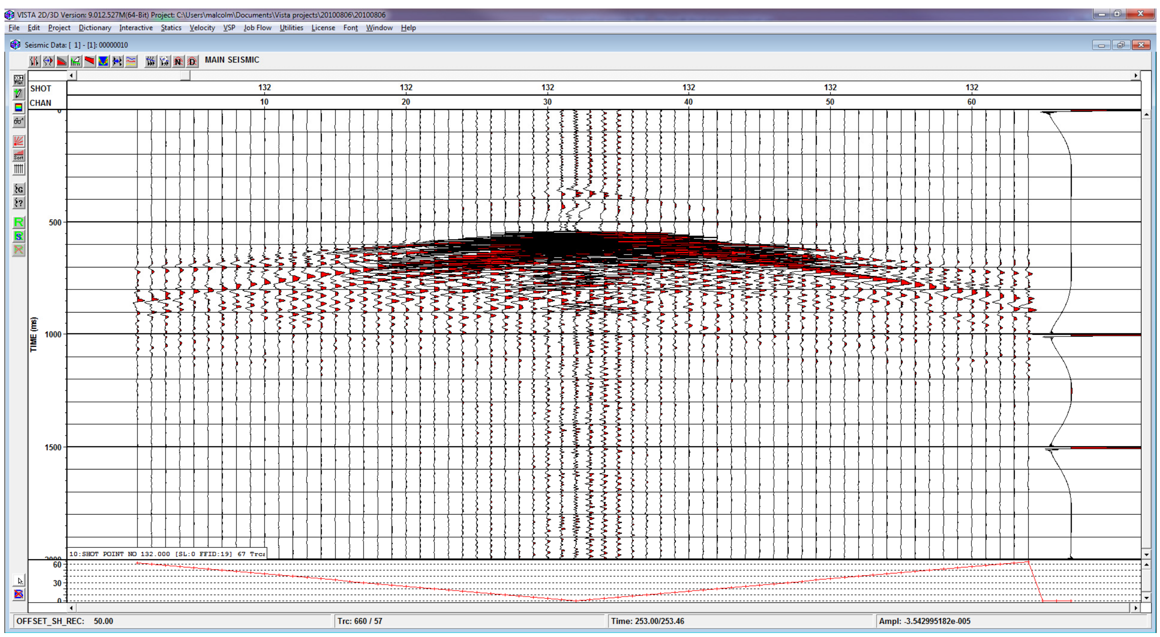


FIG 7. An example record from the thumper tests with the release of the hammer, and the impact both visible.

Figure 8 shows the changes in the travel time of the hammer for the cases of tension increasing and decreasing. There is some hysteresis apparent as the bands tend to settle after several thumps, thereby losing a small amount of tension. It is apparent that the change in drop time is almost three times (100msec to about 300msec).

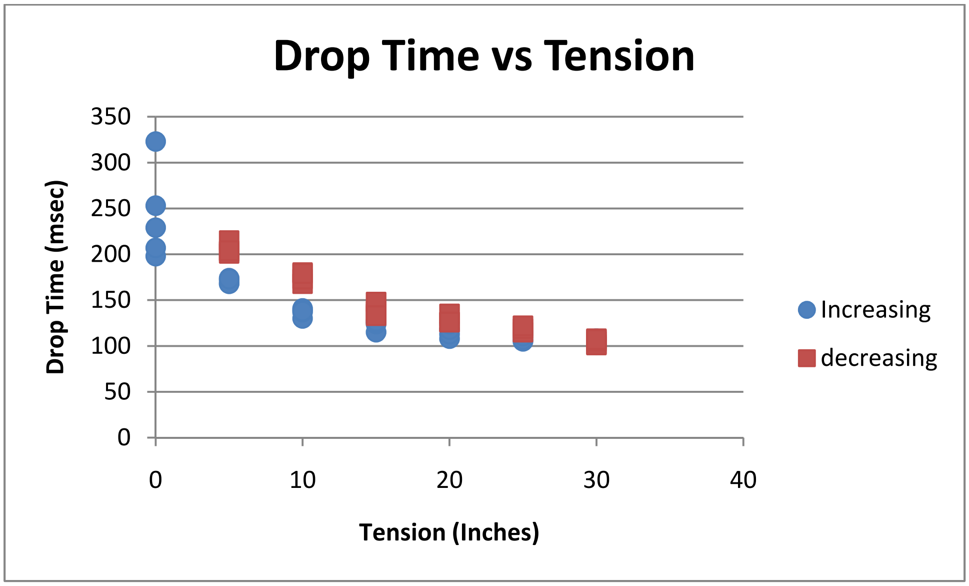


FIG 8. The travel times for the hammer for increasing tension and decreasing tension.

Another parameter measuerd was the maximum amplitude measured for each setting of the tension control. As is shown in Figure 9, there is a three times change in amplitude over the range of tension adjustment.

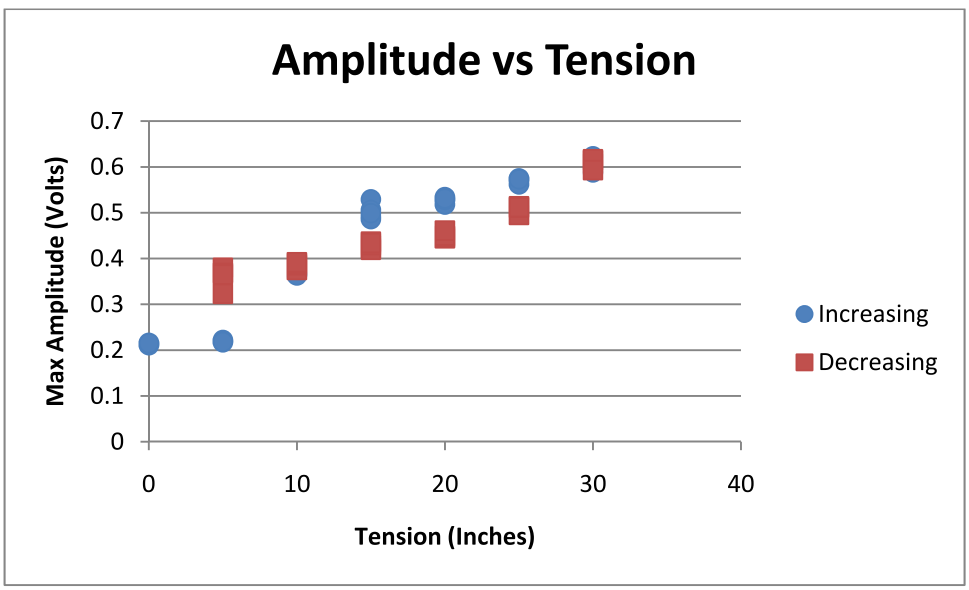


FIG 9. The maximum amplitude related to different tensions.

A cross plot of drop time and amplitude is shown in Figure 10. The relationship appears fairly linear for drop times less than 150msec. It is likely that with no tension on the bands, the hammer release is not as immediate due to friction in the system – in fact there were times when the hammer did stick in the raised position. The measurements with no bands installed are therefore suspect, and should not be included in the analysis.

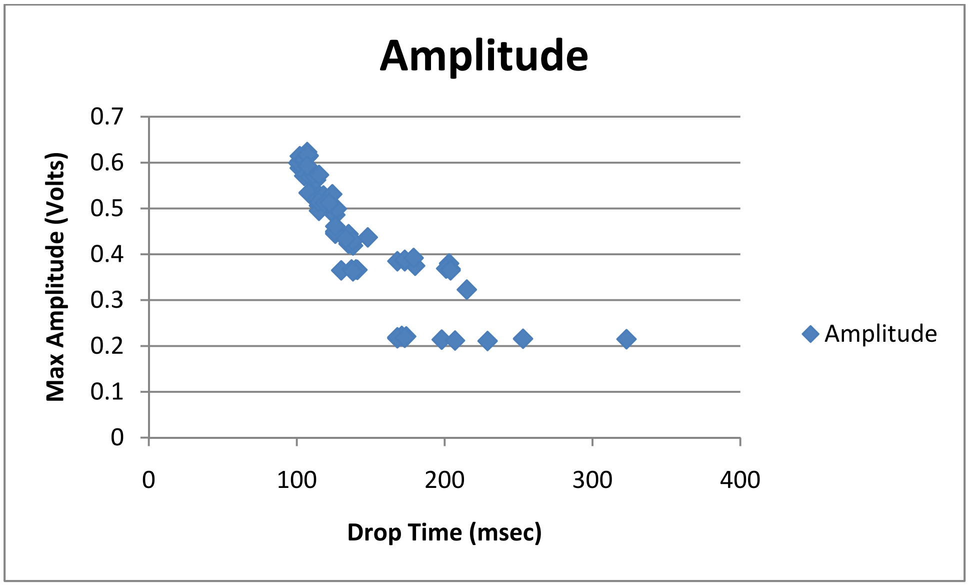


FIG 10. The cross plot of Drop Time vs Max Amplitude. Below 150msec this is linear.

The next measurement was the spectrum for each different tension. These are shown overlaid in Figure 11 for one gather from each different tension during increasing tension positions. The graphs are very similar, showing no major change in spectrum between no tension and maximum tension. The tension is given in inches, as this was the easiest way to set the elastic bands on the machine. A better measure is the holding pressure in the hydraulics which would be more consistent, but this was not available for this test.

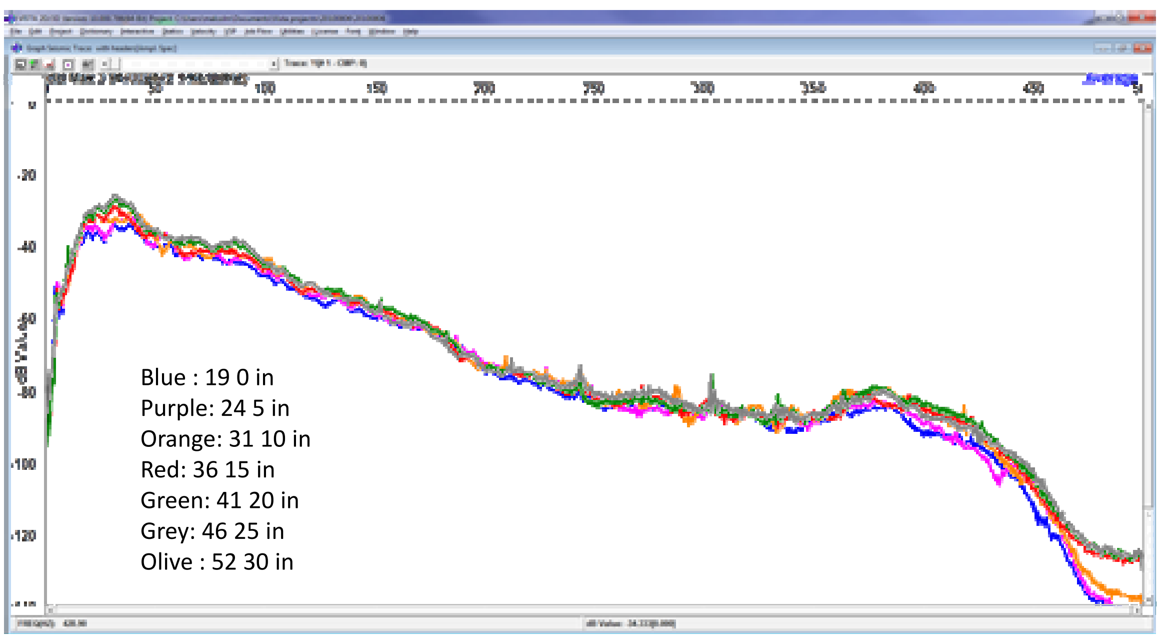


FIG 11. An overlay of spectra for seven different thumper band tensions.

A zoom of the first 100Hz of the spectra is shown in Figure 12 and demonstrated a small amount of amplitude change around 30Hz. The amplitude only increases by a few decibels over the range of tensions, showing that there is no apparent high frequency content with higher tension. Further analysis if thumper output is required to further quantify this change. This will include the accurate measurement of impact velocity of the hammer related to apparent energy, and the hydraulic pressure monitoring on the elastic frame cylinders.

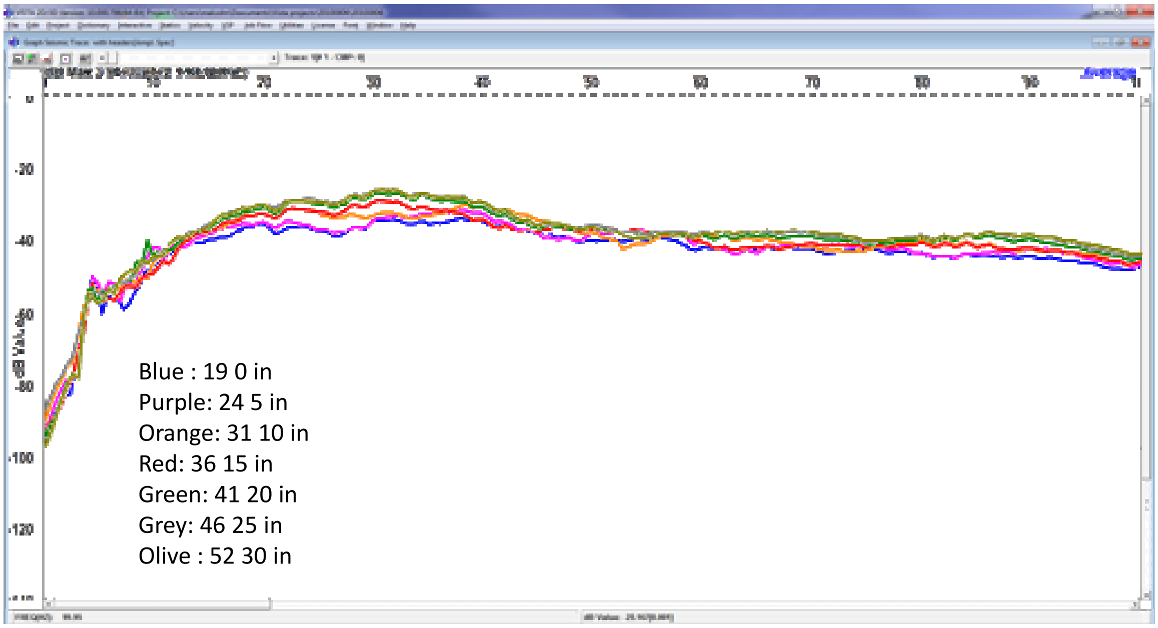


FIG 12. A zoom of the first 100Hz of the thumper spectra.

## 2010 GEOPHYSICS FIELD SCHOOL

This year the seismic section of the University of Calgary Geophysics Field School was held at Priddis, with the major component being a 3C 2D seismic line shot over 2.5Km along a road allowance running east-west from the south of the University of Calgary Rothney Astrophysical Observatory to the Priddis Valley Road. The line is on the east flank of the triangle zone, and was intended to provide a better interpretation of the structure underlying the south field of the observatory property. Geophone spacing was 10m and shots were every station. The geophones were SM7 three component singles and were provided by ARAM Rental Corporation, who also provided the 24 channel RAM units for data acquisition. The recorder was the University of Calgary SPMLite and the source was the University of Calgary EnviroVibe.

Data quality was good, with similar results to the 3C-3D shot in May mentioned above. Figure 13 is a sample record from this survey. Events are visible down to 2500msec in this data, and there is a great deal of detail in the shallow section.

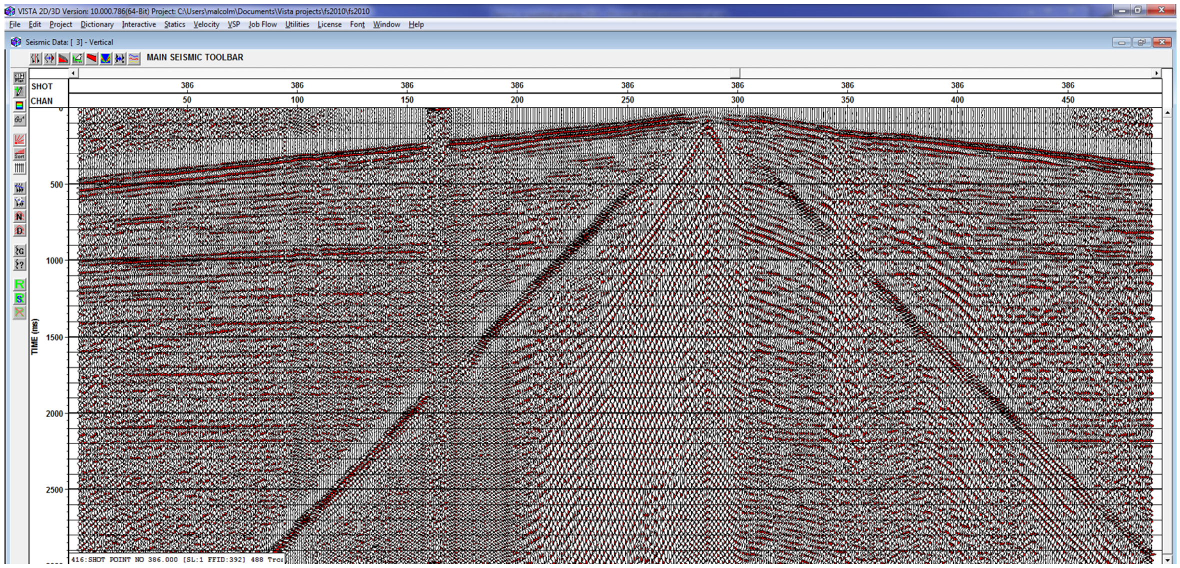


FIG 13. A record from the U of C 2010 Geophysics Field School survey.

The processed section in Figure 14 shows several deep horizons and the east dipping shallow structure which outcrops along the line. These shallow events are the main focus of the ongoing work at Priddis, as they consist of the sandstone / shale sequence being investigated for carbon dioxide sequestration over the next few years. Some of the sandstone layers outcrop on the seismic line, in some places forming local ridges or high points, one of which is shown by the elevation profile (green in Figure 11) at approximately CDP 870.

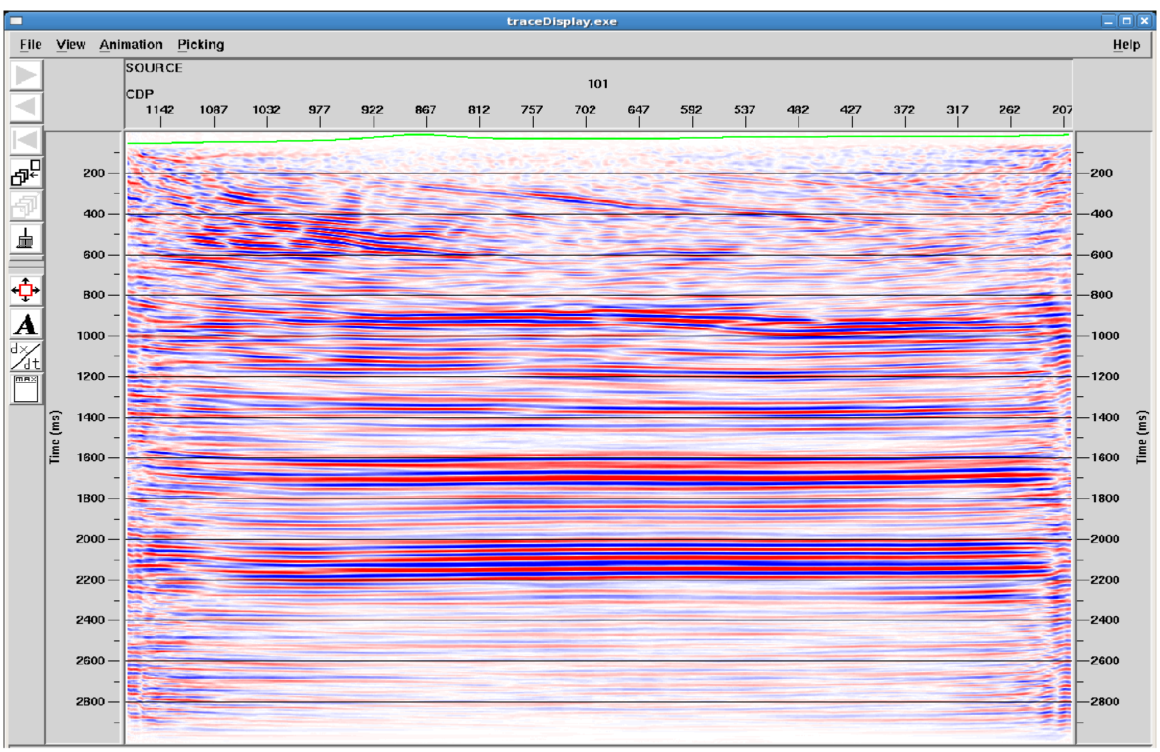


FIG 14. The processed section from the 2010 Geophysics Field School line.

## CONCLUSIONS

Data from all these field projects is available.

The Vectoreseis VSP was a successful first deployment of this tool, and provided some interesting results. This tool is now in use as a VSP system for shallow work, and has shown some excellent results.

The 3C 3D survey at Priddis gave some expected results, but came up short on the converted wave data quality, mainly due to the restricted offset range. Another survey here is indicated, with an expanded shot spread to the east and west of the receiver spread area.

Work will be continuing on the thumper analysis to try to increase the output frequency, since the device was designed for shallow high resolution work.

The Field School line provided good quality data, with further processing yet to be completed. As a further guide to the structure of the area, a parallel line one mile to the north is being investigated for Field School next year.

## ACKNOWLEDGMENTS

Thanks to High-Definition Seismic Corporation for the supply of the Vectorseis VSP tool, and Geokinetics for the use of the surface Vectorseis sensors, and the recording system, and personnel from both companies who assisted in the field for the survey.

Thanks to Aram Rental Corporation for the use of the Sensor 3C SM7 geophones and the 24 channel RAM units for the May 2010 3C 3D survey and the 2010 Field School project.

We thank all the students and staff of CREWES for their assistance on these field projects, and the GOPH549 undergraduate students for their work during the Field School project.

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