DAS and seismic installations at the CaMI Field Research Station, Newell County, Alberta

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ABSTRACT

The Containment and Monitoring Institute (CaMI) has installed Distributed Acoustic Sensing (DAS) optical fiber in two wells and along a trench at the Field Research Station (FRS) in Newell County, Alberta. One of the 350 m deep wells has both straight and helical fibres cemented on the outside of fiberglass casing. Zero-offset vertical seismic profile (VSP) data and walkaway VSP data have been collected along multiple azimuths from this well, using an envirovibe source over a 10-160 Hz sweep over 16 s. Two different interrogators were used to record the data over separate surveys, with both yielding excellent VSP data quality. A comparison of DAS to geophone data has been started through having 24 3C geophones also cemented on the outside of the casing. Some envirovibe shots have been recorded into the 1.1 km long trench fiber with an output trace spacing of 0.25 m. The shot records are dominated by unaliased surface waves.

In addition to the DAS fiber, 100 3C geophones were buried over a 10 m x 10 m grid centered in a CO_2 injection well at the FRS (Figure 1b). These geophones were glued into PVC tubing and drilled to a depth of 1 m below surface. This array will be used for microseismic recording by CaMI at the site and also for some limited imaging.

INTRODUCTION

CREWES has engaged in collaborative research with CMC Research Institutes at the Containment and Monitoring Institute's (CaMI) Field Research Station (FRS) in Newell County. Alberta. CREWES supports graduate students and research staff working on seismic data that is provided by CaMI to CREWES for collaborative research.

Figure 1 shows the layout of wells and monitoring technologies at the FRS. Relevant to this study are the locations of the monitoring wells (green dots) and the southwest – northeast trending trench that passes closely to the wells. The background grid shows the design of a multicomponent seismic survey that was recorded in 2014 as a baseline survey for the FRS time-lapse program. The denser inner grid had shot and receiver lines at 50 m intervals to image a target reservoir at a depth of 300 m, and the outer grid had a shot and receiver line spacing of 100 m to image a deeper target at 500 m depth. Shot and geophone intervals along the lines for both grids were 10 m.

INSTALLATIONS

A 5 km loop of Digital Acoustic Sensing (DAS) optical fiber was installed in two observation wells at the FRS, as well as in a 1.1 km long trench. The purpose is to evaluate straight and helical wound optical fiber cable for VSP data in the observations wells, and to compare these data with geophone data from one of the wells. Also, we are evaluating surface seismic acquisition using helical wound fiber and single-mode fiber that is buried at a depth of 1 m in the trench that is shown in Figure 1.

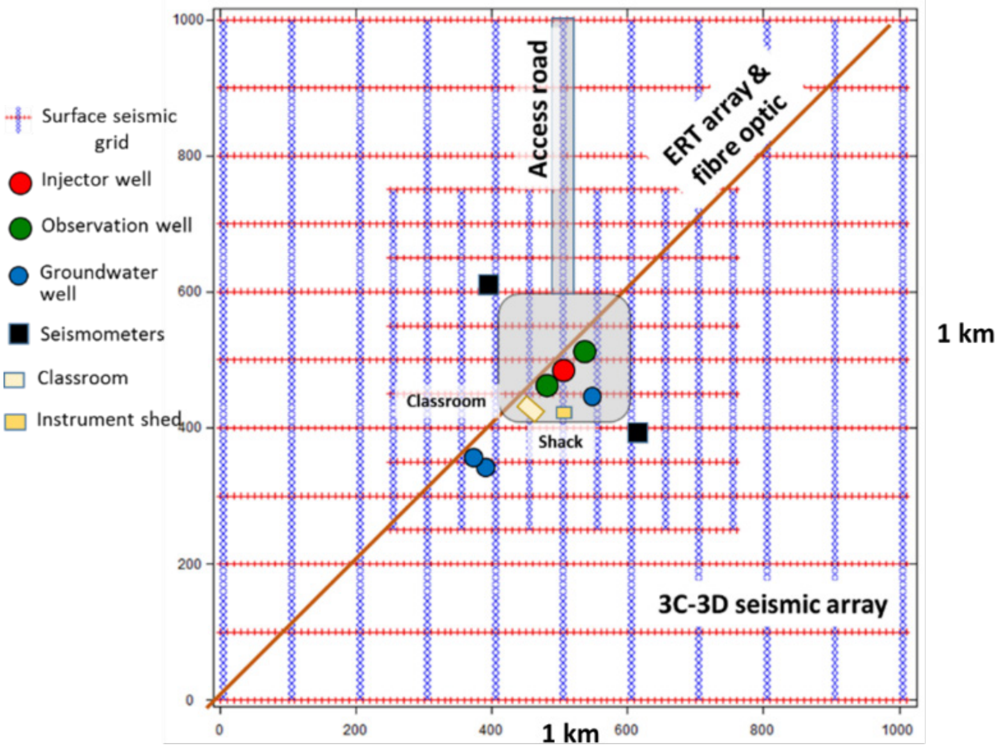


FIG 1. Layout of the CaMI Field Research Station in Newell County, Alberta

The layout of the fibre loop is shown in Figure 2. The loop starts and terminates in the office trailer and there are 4 junction boxes that contain fiber splices to complete the loop.

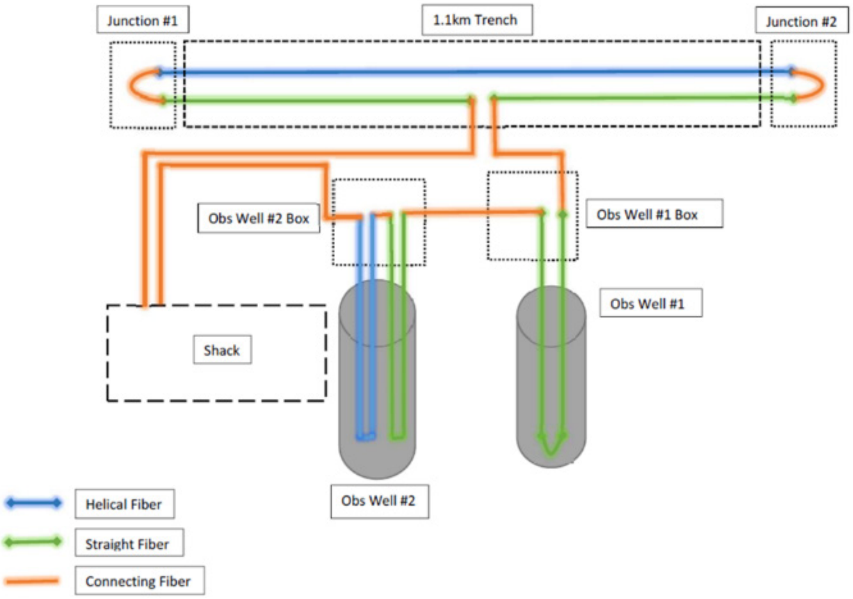


FIG 2. DAS fiber loop installed at the CaMI field research station

Also in 2017, a permanent array of 3C geophones was buried at the FRS. Figure 3 shows the layout 100 3C geophones that were buried over a 10 m x 10 m grid centered in a CO_2 injection well. These geophones were glued into PVC tubing and drilled to a depth of 1 m below surface. This array will be used for microseismic recording at the site during CO_2 injection, and also for some limited imaging around the injection well.

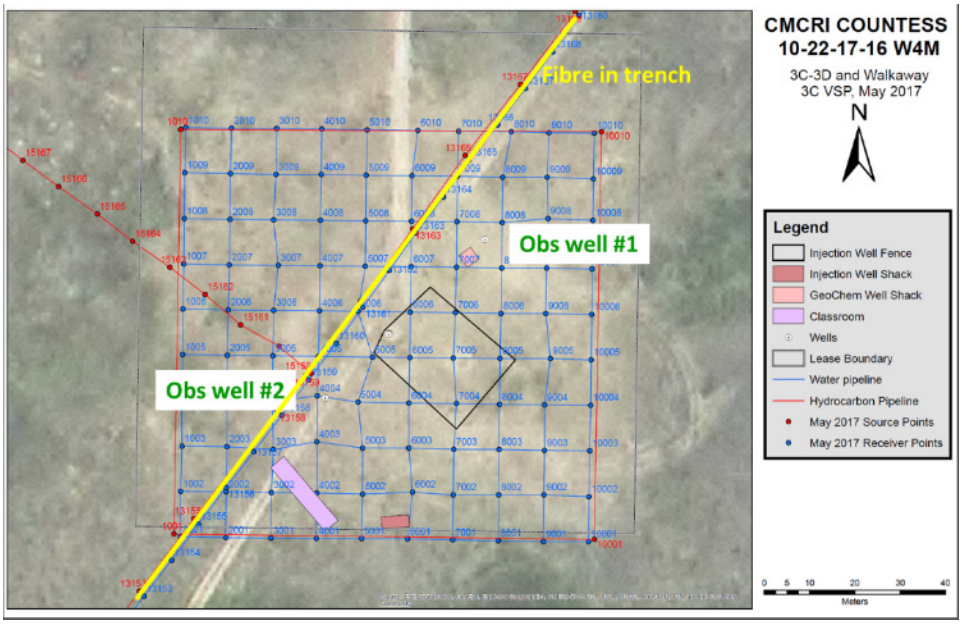


FIG. 3. Layout of buried 3C geophones at CaMI.FRS. The locations of the observations wells and trench that contain DAS fiber are also shown.

Figure 4 shows how the 3C geophones were cemented into the base of PVC tubes. The surface of the tube was slotted so that the horizontal components of the geophones could be aligned in each of the holes. For all geophones, the H1 component was oriented to magnetic north.

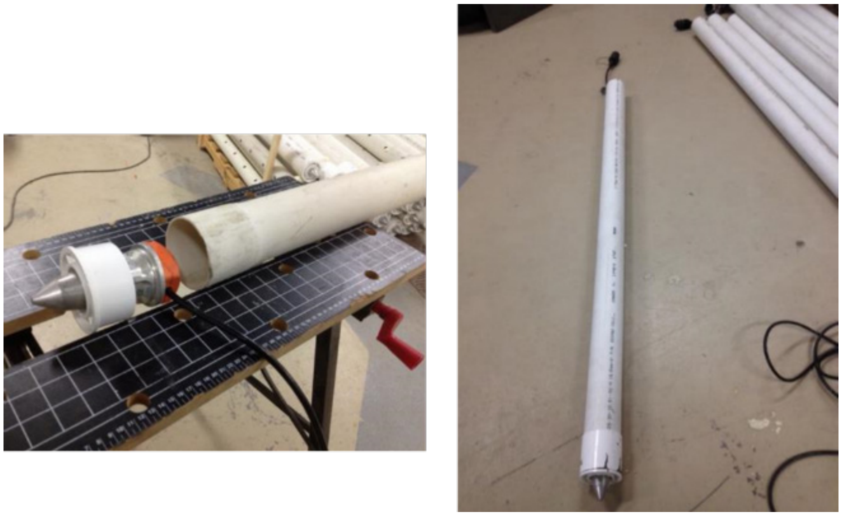


FIG 4. Preparation of 3C geophones for permanent burial at CaMI.FRS

Figure 5 shows how the geophones being oriented in the shallow holes during installation.

FIG 5. Malcolm Bertram orienting 3C geophone during installation.

In May, July and October 2017 seismic surveys were undertaken at the site, including walk-away VSP data and a 2D line recorded along the trench. For the May surveys, data were recorded with surface, buried and borehole geophones only. In July and October, seismic data were recorded by a Silixa DAS interrogator provided by the Lawrence Berkeley National Laboratory. Some of these data are presented in this year's research report by Gordon and Lawton (2017). Additional DAS data were collected in October by Fotec Solutions and some of these data are also presented in this year's report by Hardeman et al. (2017).

ENVIROVIBE DATA

An example shot gather recorded with the 5 km DAS fiber is shown in Figure 6, and consists of approximately 20,000 output traces at a spacing of 0. 25 m. The gauge length for the acquisition was 10 m. The blue lines identify the approximate locations of the junction boxes along the 5 km fiber. Exact locations of the start and end points of each of the fiber segments (wells, trench) were identified from tap tests on the fiber. The 3 'V' panels on the display in Figure 6 are the VSP data recorded in the two observation wells, and the V-shape is due to the fiber being looped in the well, with both upward and downward segments. The other traces in the gather are data collected from the straight and helical wound fiber laid in the trench.

An example of a DAS shot gather from observation well #2 (Figure 1), extracted from the full dataset, is shown in Figure 7. The VSP DAS data from both the downward and upward segments of the fiber loop are very similar. For comparison. The geophone data collected from the down-hole 3C geophones in this observation well are shown superimposed on the DAS data over the correct depth interval (190 m to 310 m). Both geophone and DAS datasets show good quality direct down-going and up-going P-wave reflections that kinematically are very similar. These data were processed by Gordon and Lawton (2017) through to a corridor stack. Hall et al. (2017) examine the improvements in the signal to noise ratio of the DAS data as a function of vertical stack (number of sweeps at each VP).

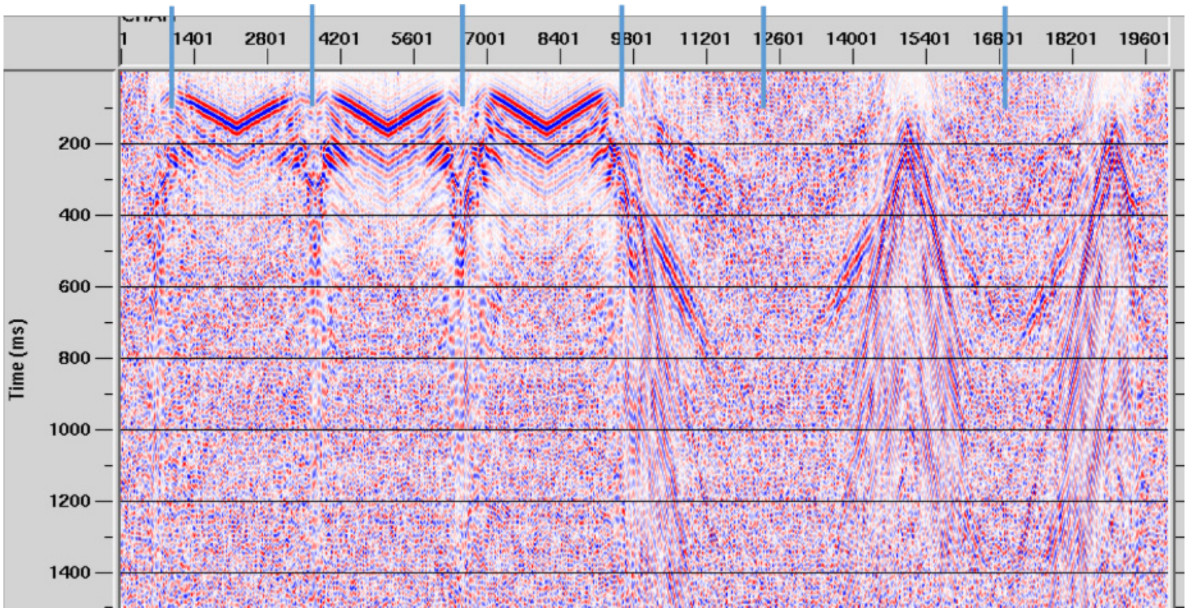


FIG 6. Raw shot gather (with agc) into 5 k m fiber loop. Recorded with Silixa IDAS interrogator.

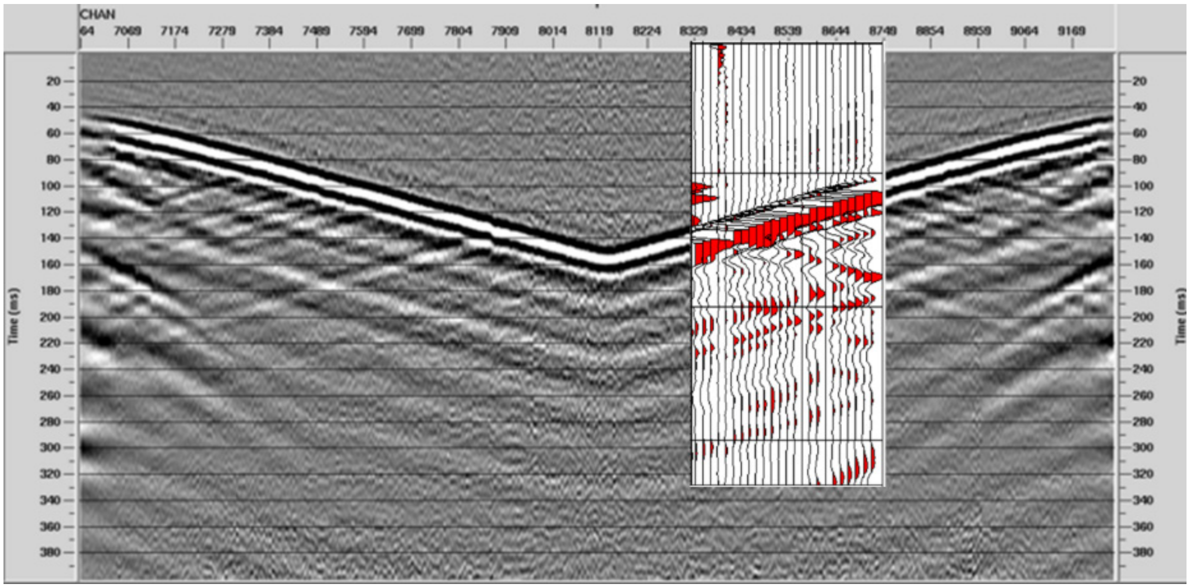


FIG 7. Raw VSP gather (with agc) from Observation Well #2, recorded with Silixa IDAS interrogator. Geophone data from 190 to 310 m depth are superimposed on the DAS data.

In the May acquisition program, some test shots were recorded into the fiber that was laid in the trench shown in Figure 1. Raw data from one of these shots is shown by the right-hand parts of Figure 6 and also in Figure 8. These data are derived from 4 sweeps that were correlated and vertically stacked using a diversity stack algorithm (Hall et al., 2017). The figure shows weak first arrival data but high amplitude surface waves that are unaliased due to the small output trace spacing (0.25 m).

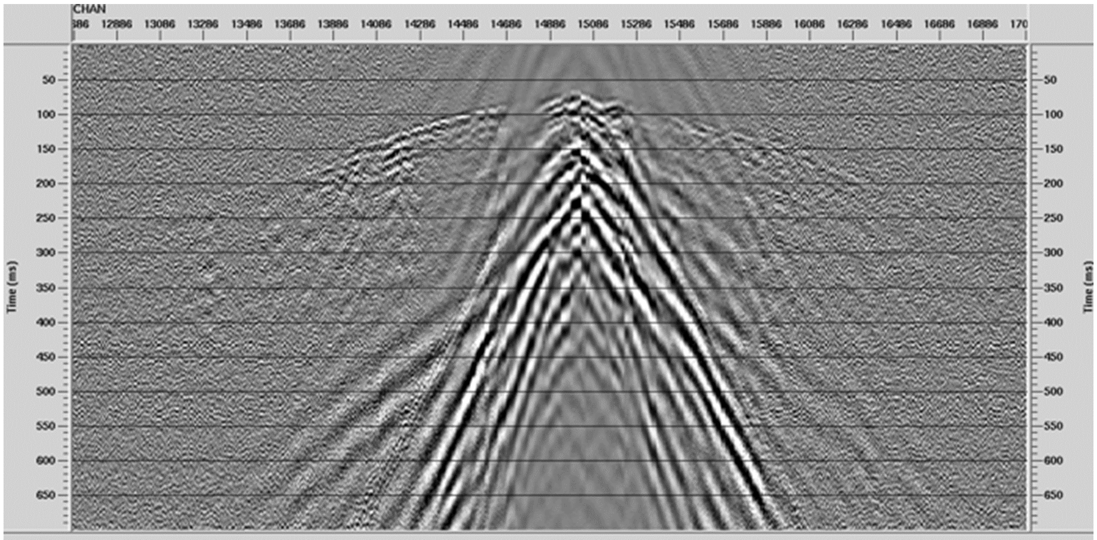


FIG. 8. Raw DAS shot gather (with agc) gathered from the trench fibre optic cable. Source was an envirovibe with 4 sweeps 10 – 160 Hz.

The same record, after noise attenuation, deconvolution and bandpass filter is shown in Figure 9. Most of the surface waves have been attenuated and the first arrival data are more easily seen in the display. Significant variations in apparent first arrival time are evident, possibly illustrating rapid lateral variations in the receiver static corrections.

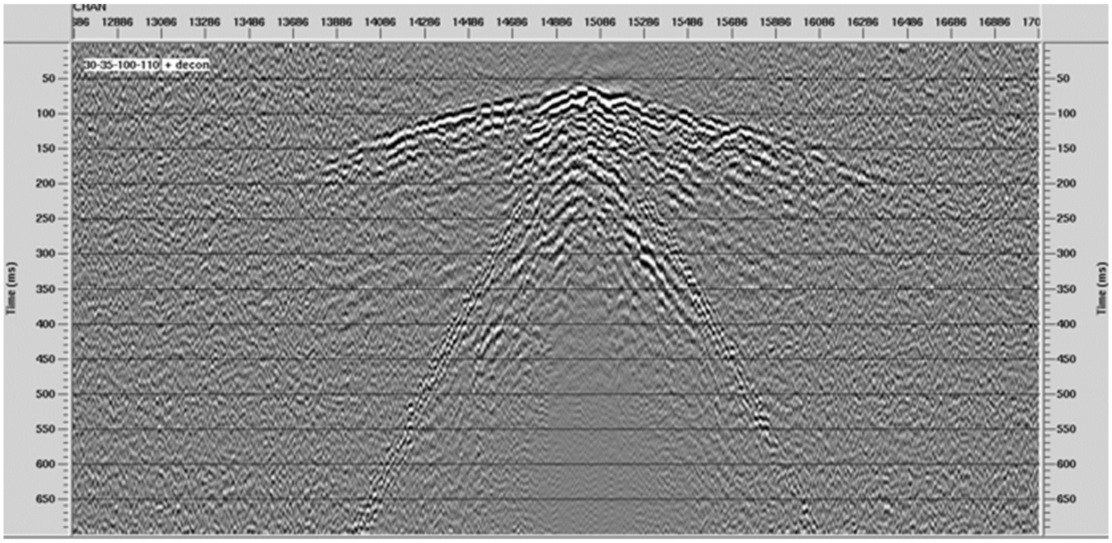


FIG. 9. DAS shot gather (with agc) shown in Figure 7 after noise attenuation, deconvolution and bandpass filter.

No obvious reflections are visible in the data in Figure 9 but the full dataset will be processed through to a migrated section as soon as the data are available. Of interest in the highly frequency airwave data that is evident in the processed shot gather. This is interpreted to be due to ground-coupled airwave energy that is captured in the DAS data.

THUMPER DATA

Some test records from both the DAS and geophone recording systems were obtained with the CREWES multicomponent accelerated weight drop source. This source is described by Lawton et al. (2016). The source is a model A200 weight drop device with a hammer of mass 200 kg accelerated by compressed nitrogen operating at 1000 psi. P-wave data are collected with the source operating in a vertical force orientation. A pivot system enables the source to generate both P-wave and S-waves. The source can rotate ± 45 degrees transverse to the longitudinal axis of the trailer, in order to generate down-going P-wave and S-waves simultaneously. Pure-mode down-going S-waves are generated by subtracting records taken with the mast rotated in the positive and negative tilt modes.

Figure 10 shows a 3-component shot gather recorded from a source point located near the centre of the 1.1 km long line, and the source operating in vertical force mode. Clear first arrival data are visible and the record is dominated by high-amplitude surface waves. Some weak reflection data are seen under this noise on the far offset traces of the vertical component record. Refracted arrival velocities from the vertical component first arrival data are approximately 2700 m/s.

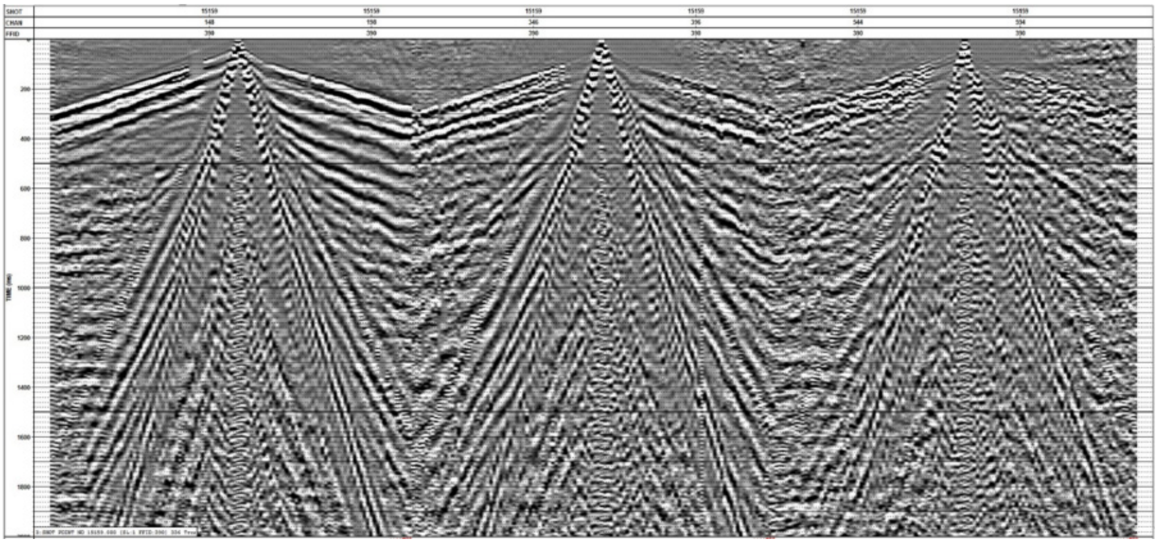
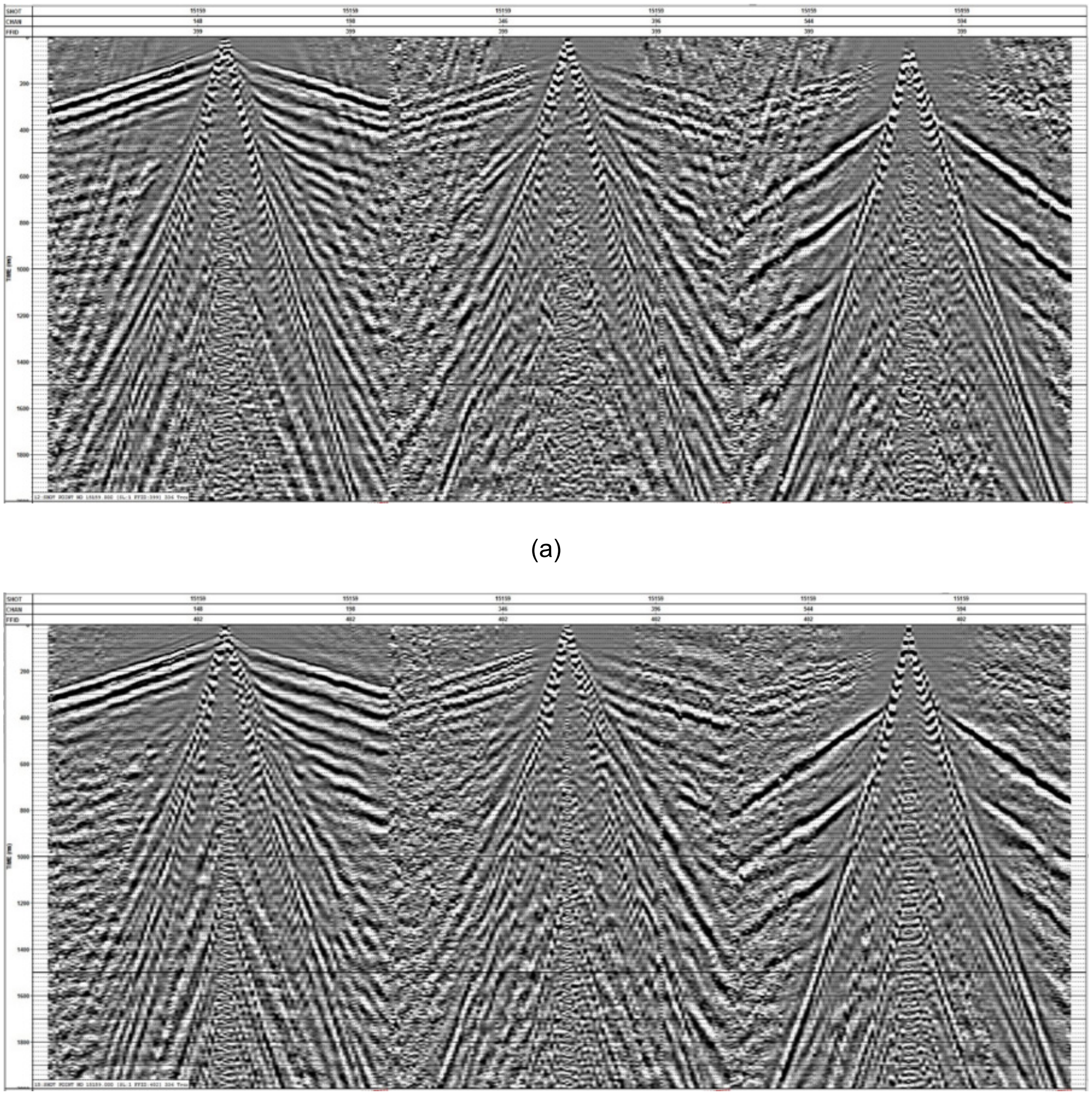


FIG. 10. 3C geophone shot gather collected along the 2D trench line with a vertical source configuration. Gather order from left to right is vertical, inline and crossline.

Figure 11 shows the same source-point location as that for Figure 10, but with the source operating in a cross-line configuration. This record shows the source impact at +45 degrees to vertical (Fig 11a) and at -45 degrees to the vertical (Fig 11b). Clear polarity reversals are evident in the refracted SH arrival on the crossline geophone component. This record also shows what appear to be multiple refracted arrivals, all with the same apparent velocity of approximately 1500 m/s. The origin of the multiple refractions is uncertain.



(a)

(b)

FIG. 11. 3C geophone shot gather collected along the 2D trench line with a cross-line source configuration. Gather order from left to right is vertical, inline and crossline. (a) source strlking to southeast; (b) source striking to northwest.

Figure 12 shows the same source-point location as that for Figure 10, but with the source operating in the in-line configuration. This record shows the source impact at +45 degrees to vertical (Fig 12a) and at -45 degrees to the vertical (Fig 12b). Clear polarity reversals are evident in the refracted SV arrival on the crossline geophone component. Similar to that seen in Figure 11, this record also shows what appear to be multiple refracted arrivals. However, the SV refracted velocity is significantly lower than the SH mode refracted arrivals, with an apparent velocity of approximately 900 m/s. The origin of the multiple refractions is uncertain, similar to those observed in the cross-line data. In both the cross-line and in-line source orientation, there is some leakage into the in-line and cross-line geophone components, respectively, which could be indicative of S-wave splitting. This is yet to be investigated.

The surface waves displayed in the horizontal components shown in Figures 11 and 12 show that the Love waves are significantly less dispersive than the Rayleigh waves.

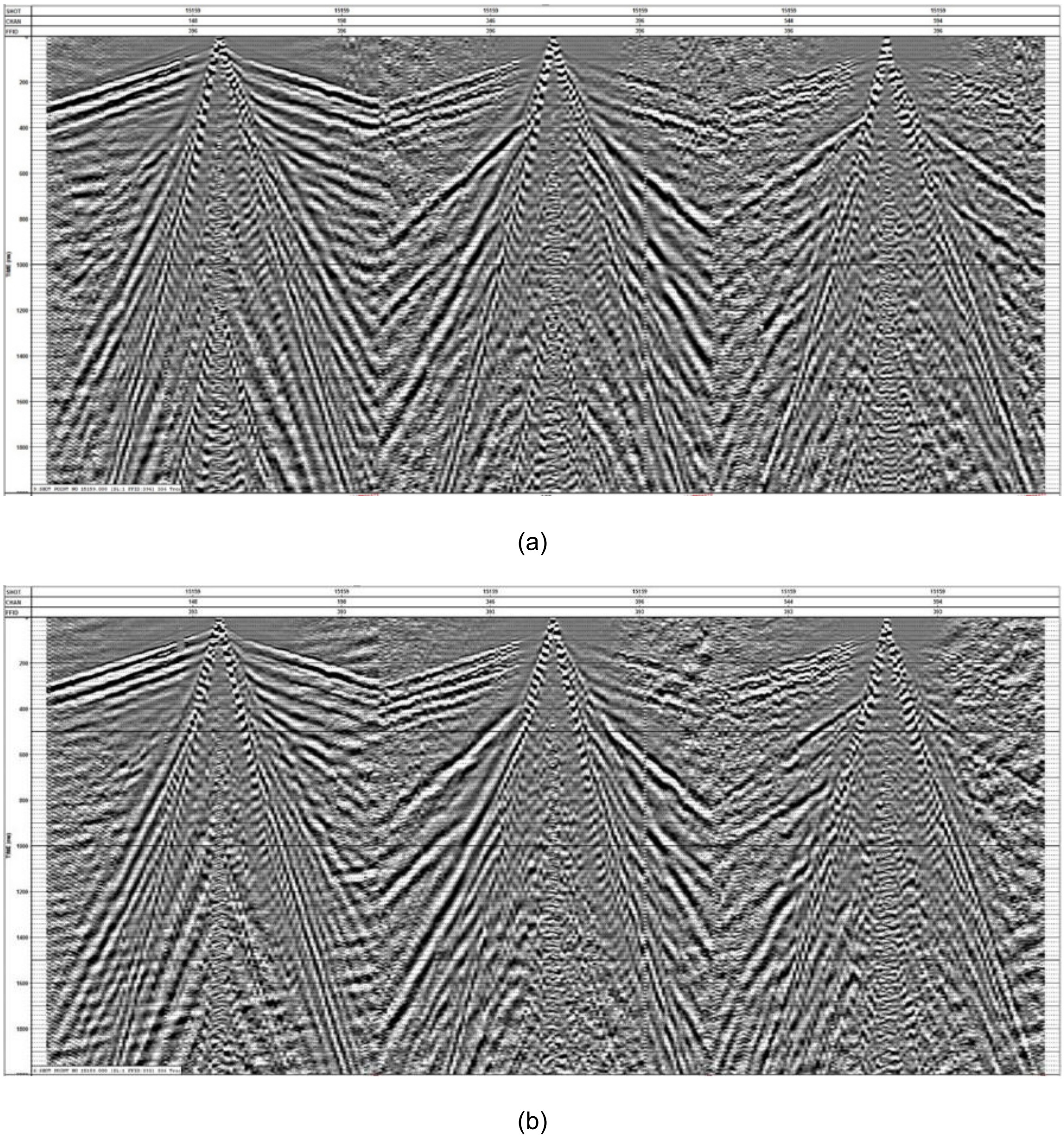


FIG. 12. 3C geophone shot gather collected along the 2D trench line with a in-line source configuration. Gather order from left to right is vertical, inline and crossline. (a) source strlking to southwest (b) source striking to northeast.

CONCLUSIONS

Optical fiber deployed at the CaMI Field Research Station has generated excellent quality DAS VSP data, with clearly resolved upgoing P-wave reflections visible in the data. Some direct down-going S-wave data has also been recorded. DAS acquisition into fiber deployed in a trench is dominated by surface waves. Additional process is required in order to determine if reflection data can be recovered from these data.

Shear wave source acquisition into surface and down-hole geophone has generated P and S-wave data that will be used to complete the shallow components of the P and S velocity models at the FRS. Some evidence of S-wave splitting has been observed in refraction data recorded at the sites.

ACKNOWLEDGEMENTS

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