VSP processing of Distributed Acoustic Sensing and geophone data at CaMI Field Research Station, Newell County, Alberta

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Summary

Two Vertical Seismic Profiles (VSP) were acquired in May and July of 2017 at the Containment and Monitoring Institute Field Research Station (FRS) in Newell County, Alberta. These surveys were recorded using two different receiver types; a 24-level 3C geophones array and an integrated fibre optic cable (DAS and DTS). A zero-offset processing flow was completed for two vibe points and an 80 m offset vibe point for both the fibre optic cable and geophone array. Before processing, a depth calibration step was necessary to estimate the exact depth for each trace in the fibre optic data set. There was an accurate result between the cross-correlation of the first and last geophone trace, a difference between 0 to 3 m was calculated from the calibration. After the processing flow was completed, a good match was obtained between the corridor stack of both the down-going and up-going segments of the fibre loop, as expected. A time difference of approximately 20 ms between the DAS and geophone data was also noticeable which might be caused to the difference between the signal recorded by the geophones and the fibre optic cable. A synthetic seismogram generated with Syngram shows a good match with the DAS corridor stacks.

Introduction

As one of the objectives of the Research Field Station (FRS) is the implementation of new technologies for a better understanding and development of monitoring program for the CO_2 injection site. Fibre optic cables were permanently deployed in the observation wells, particularly the observation well 2, also called geophysical well has an integrated fibre optic cable (DAS and DTS) as well as a 24-level 3C geophone array. In this opportunity, we will show the processing results of the DAS data recorded in May and July 2017 for several vibe points. The results are compared with the geophone data set. Even though a helical-wound fibre optic cable was implemented in the observation well 2, the data set was not analyzed in this report, our main focus is on the straight fibre optic cable and the vertical component of the 3C geophone data set.

Theory and Method

Distributed Acoustic Sensing (DAS) is a fibre optic technology that have been developing recently. DAS measurements utilizes a standard fibre optic cable instead of geophones for seismic sensing along the well. The fibre optic cable is interrogated by a special device on the surface, called an “Interrogation Unit” (IU), which measures deformations along the optical fibre caused by impinging seismic waves (Mateeva et al., 2014). The interrogator unit sends laser pulses along a fibre in the well. A tiny part of the laser light is back-scattered by random microheterogeneities naturally present in the fibre (Rayleigh scattering). Changes in the Rayleigh back-scattered pattern occur when a seismic wave deforms the fibre and these are translated into seismic measurements (Mateeva et al, 2014).

Two Vertical Seismic Profile (VSP) data sets were acquired this year at the Field Research Station (FRS) during the months of May and July. In this opportunity, three source points were processed. Prior the processing, a depth calibration of the fibre optic data was necessary to determine the depth of the

DAS channels. Determining the DAS channel depths in the fibre optic cable is usually not a problem for short and simple near-vertical wellbores, if the total length of the fibre and the precise channel spacings are known. The total length of the fibre or the exact channel spacing is not always known, and the fibre may also suffer from tortuosity along the wellbore (Wu et al., 2015). In this case, the depth calibration or tie between the DAS data and the geophones was performed with a cross-correlation of the DAS data and the first and last trace of the geophone array. An example of the cross-correlation result is shown in Figure 1, where the DAS trace corresponding to the geophone trace depth (194.9 m) will be the cross-correlation function of maximum amplitude that crosses the zero-lag time (red line), in this case equal to 500 ms. This calibration was done for the three vibe points and the difference in the results between the calibration of the first and last geophone depth vary from 0 to 3 meters.

Then, it was possible to identify the exact depth of the traces of the fibre optic data set and procced with the processing flow. DAS VSP data processing largely follows the typical VSP processing sequence. However, there are aspects of the data that are specific to DAS VSP and the well trajectories that require additional processing attention (Wu et al., 2015). A standard zero-offset processing flow was modified according to the fibre optic configurations from (Bubshait, 2010).

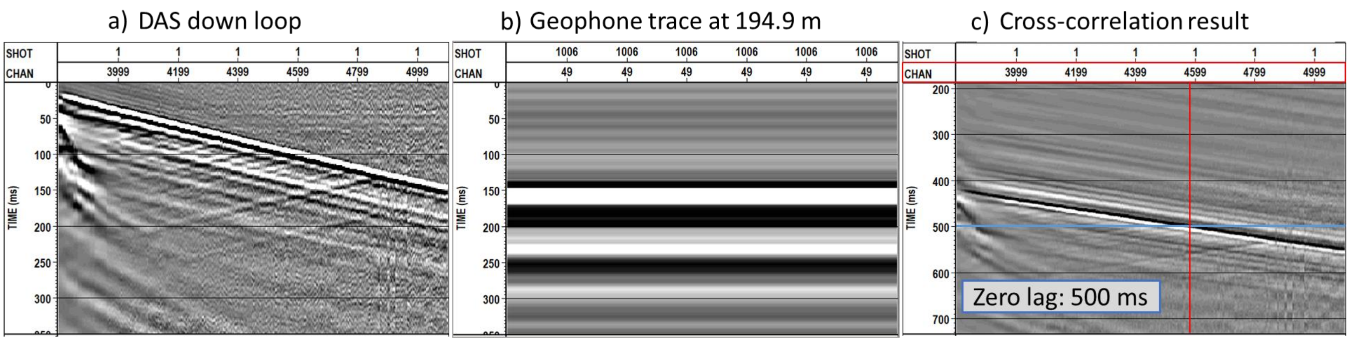

FIG. 1. Example of cross-correlation for vibe point 132, line 21 from July 2017. a) left hand side of DAS gather, b) geophone trace at 194.4 m. c) cross-correlation result. Red line highlight crossing of zero-lag line (500 ms) and maximum amplitude. Maximum amplitude cross-correlation function crossing zero-lag time is highlighted in red.

Results

The Figures 2-4 correspond to the outside corridor obtained for both the fibre optic and geophone data sets of the vibe points mentioned previously. Generally, there is a good match between the corridor stack of the upgoing and downgoing fibre loops, as expected. Comparing these results with the geophone data set, it is noticeable a time shift which is more evident in the high amplitude reflector corresponding to the reservoir. For example, for the zero-offset gathers, the high amplitude reflector is at approximately 250 ms in the fibre optic data set and at approximately 275 ms in the geophone array; and for the offset gather, the high amplitude reflector is at approximately 270 ms in the fibre optic data set and at approximately 290 ms in the geophone array. One possible cause of the time shift could be a miss match between the recording start time of the geophones and the fibre.

Another possible cause might be the fact that each data set was recording a different measurement, the geophones record particle velocity and the fibre optic cable record Distributed Acoustic Sensing (DAS) measurements corresponding to strain. To compare DAS signal with geophone, one must convert from strain or strain-rate to particle velocity and take into account that, like ultrasonic transducers, radar antennas, or spatially distributed groups of geophones or hydrophones, the DAS signal intrinsically represents an integrated array response of conceptual point sensitivities (Miller et. al, 2016). Few attempts to convert the DAS signal were performed with a function available in VISTA and after the depth calibration step mentioned previously, the difference between the first and last geophone was of 2 meters which is within the range of the results presented before the conversion.

The following step was to generate synthetic seismograms using the sonic logs available and testing different wavelets, this was performed using Syngram software. A ricker wavelet with a dominant frequency of 80 Hz was created. The wavelet and the sonic log from the observation well 2 were the inputs used to obtain a synthetic seismogram. The synthetic seismogram obtained is shown in Figure 5, displaying the tie between the corridor stacks of the zero-offset VSP (July survey) and the synthetic seismogram. From this seismic tie, a good match is noticeable between the down loop and up loop corridor stacks with the synthetic seismogram. Most of the events in the seismogram correlate with the events in the corridor stacks. However, there are some small differences in amplitude and a slight time shift is also noticeable.

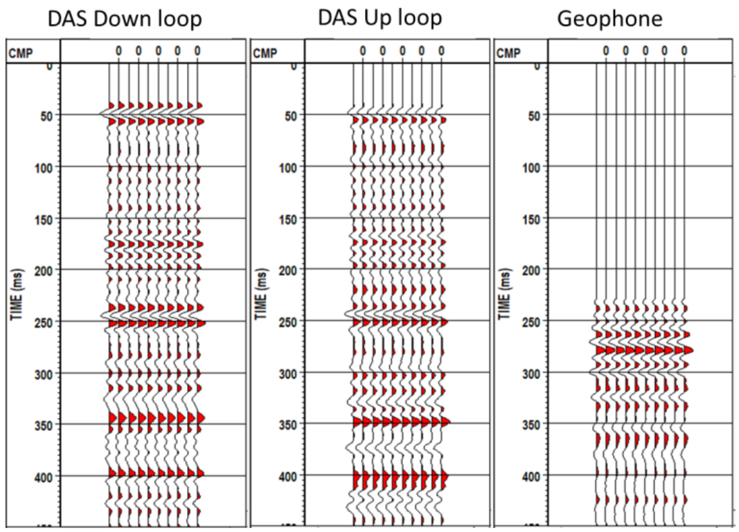

FIG. 2. Corridor stack comparison. Vibe point 159, line 13, May 2017.

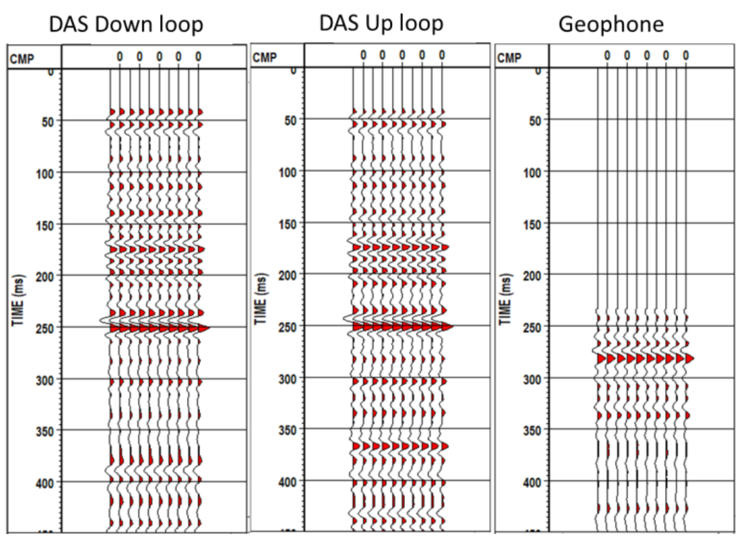

FIG. 3. Corridor stack comparison. Vibe point 132, line 21, July 2017.

Conclusions

Two VSP surveys were acquired at the Field Research Station in May and July, 2017. These surveys were acquired with a geophone array and a fibre optic (DAS) cable deployed in the observation well 2. Two zero-offset gathers and an 80 m source-well offset gather were processed using a standard processing flow. The fibre optic data set was calibrated with the geophone array to properly identify the corresponding depth of each DAS trace. There was an accurate result between the cross-correlation of the first and last geophone trace, a difference between 0 to 3 m was calculated from the calibration.

As expected, there is a good match between the corridor stack of the upgoing and downgoing fibre loop. A time difference approximately of 20 ms between the DAS and geophone data is noticeable specially with the high amplitude reflector. A synthetic seismogram was generated with Syngram and there is a good match between the DAS corridor stacks and the synthetic seismogram.

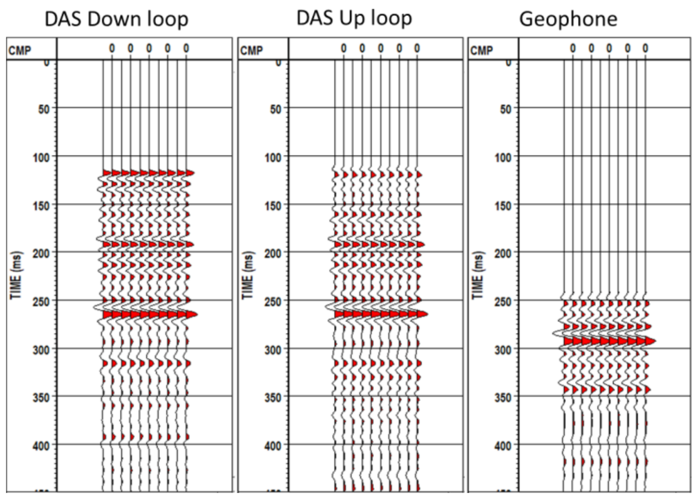

FIG. 4. Corridor stack comparison. Vibe point 139, line 21, July 2017.

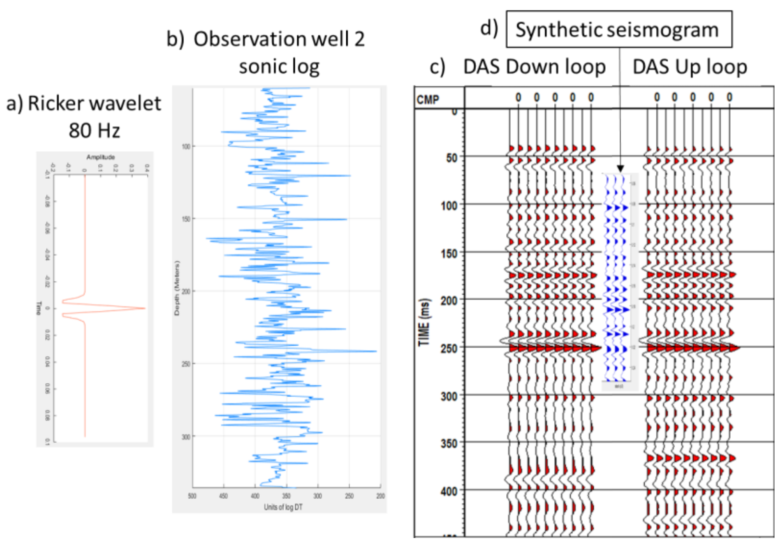

FIG. 5. Synthetic seismogram comparison. a) Ricker wavelet, b) sonic log, c) DAS down loop and up loop corridor stack and d) synthetic seismogram obtained.

Acknowledgements

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