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Processing of walk-away DAS and geophone VSP data from the CaMI Field Research Station, Newell County, Alberta

Adriana Gordon[1], Don C. Lawton[1,2], Kevin Hall[1] and Tom Daley[3]
[1]CREWES, University of Calgary, [2]Containment & Monitoring Institute, [3]Lawrence Berkeley National Lab.

Summary

As part of the FRS baseline assessment, several Vertical Seismic Profiles were acquired with the intention of testing emerging monitoring techniques such as Distributed Acoustic Sensing (DAS). We describe the processing flow and discuss the results obtained for a walkaway VSP oriented North-South and centred in the Observation Well 2. This survey was acquired in July 2017 using two recording systems: optical fibre for DAS and a 3C 24-level geophone array. After processing the different datasets, we compared the results of the stacked VSP-CDP transforms with an inline section from a 3D seismic survey crossing through the well. Overall, there is a good correlation between the events in the surface seismic and the VSP-CDP. The CO_2 injection target located at approximately 250 ms is noticeable in each dataset. Nevertheless, there is an apparent discontinuity of the event of interest across the mapped result, particularly for the fibre. This assessment shows how DAS measurements are a promising approach for subsurface imaging and continuous monitoring.

Introduction

The implementation of new technologies at the Containment and Monitoring (CaMI) Field Research Station (FRS) is a key objective of the project. One of the technologies is Distributed Acoustic Sensing (DAS), considered a rapidly developing technology with several applications for subsurface imaging and monitoring. DAS consists of the use of optical fibre for seismic sensing along a well or in a horizontal trench. The fibre optic cable is connected to a device called interrogator unit that measures the deformations generated by impinging seismic waves along the fibre (Mateeva et al., 2014).

At the FRS there is a loop of fibre optic cable installed for the study of this emerging technology and to monitor a CO_2 injection program. Straight and helically wound optical fibre are deployed in the observation wells, however on this occasion, we will focus on the straight fibre dataset. In the following sections of the abstract, we show the processing flow of a walk away VSP acquired at the FRS using DAS and also a geophone array permanently installed in the Observation Well 2. The intention is to compare the imaging results obtained from DAS and geophones while also comparing them with surface seismic sections of the FRS baseline seismic volumes.

Workflow

The FRS is located approximately 200 km southeast of Calgary in the Newell County near the town of Brooks. A North-South walk away VSP was selected for processing as it has a consistent number of vibroseis sweeps per source point (6 in this case). Figure 1a) shows the geometry of the line, where source points selected for discussion are coloured in blue and the Observation Well 2 is in orange. The offset range is from 9 m to 220 m approximately increasing from the well at each side of the line. The seismic source used for the acquisition was an IVI EnviroVibe a with a linear sweep from 10 to 150 Hz over 16 s. The recording systems included fibre optic cables with a nominal gauge length of 10 m and output trace spacing of 0.25 m and a 24-level 3-component (3C) geophone array covering at depths from 191 to 306 m with a 5 m spacing. The standard processing flow applied to the datasets is shown in Figure 1b).

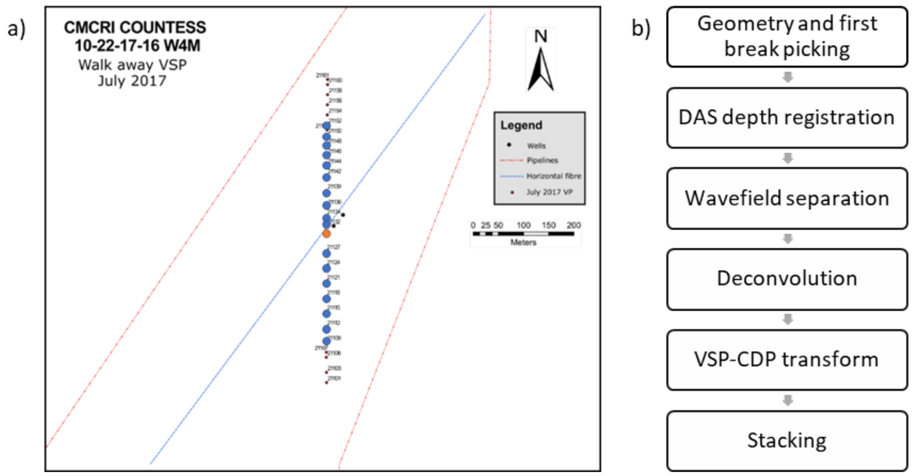

Figure 1. Walk away VSP survey. a) Geometry, b) processing flow applied.

Figure 2 shows the raw DAS and geophone datasets. There is a good identification of downgoing and upgoing waves in each dataset. As the offset increases, the arrival of head waves is noticeable in DAS dataset due to the full coverage of the fibre in the well.

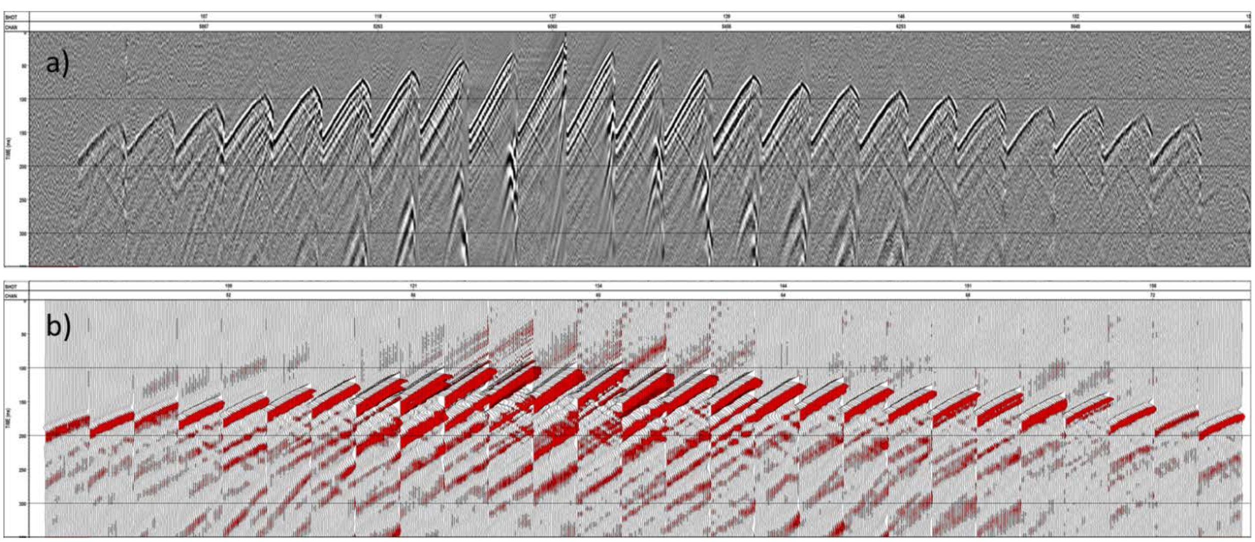

Figure 2. Raw source gathers of walk away VSP. a) Straight fibre, b) Geophones.

A median filter was used to separate the downgoing and upgoing wavefields. For DAS dataset, a median filter of 91 samples was applied and for the geophones, a median filter of 5 samples was applied. In both cases, a good separation of the downgoing and upgoing waves was obtained.

Nevertheless, DAS datasets had several downgoing events remaining in the upgoing wavefield that were removed with an F-K filter.

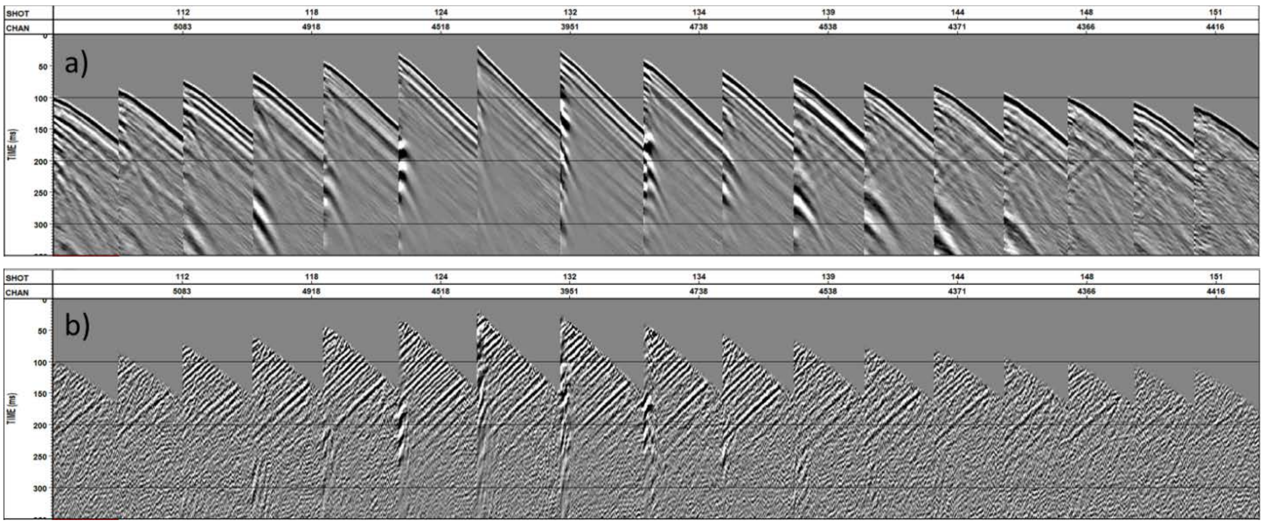

Figure 3. Wavefield separation of DAS straight fibre. a) Downgoing wavefield, b) Upgoing wavefield.

A deconvolution operator was generated with the downgoing wavefield and applied to the upgoing wavefield to remove multiples and to obtain a better visualization. An improvement in the seismic events was achieved, as the events seem sharper and continuous.

The VSP-CDP transform is used to map offset VSP data back to their corresponding reflection point (Sheriff, 2002). Among the parameters used for the VSP-CDP transform, the trace spacing output selected for the DAS was of 1 m and 2.5 m for the geophones which is similar to the trace spacing of DAS after a data selection and half of the channel spacing for the geophones. The velocity models used for the transform were obtained from the first break arrivals of a zero offset VSP. Following the VSP-CDP transform, the data from each VP was stacked (Figure 4) where the event of interest at 250 ms is noticeable and continuous along the majority of the section.

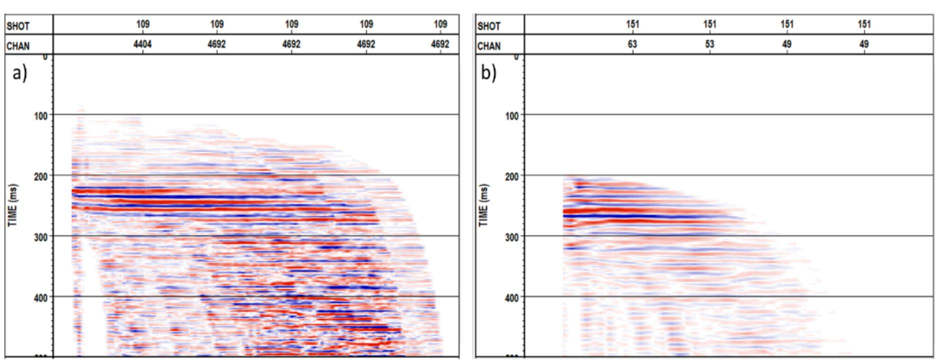

Figure 4 VSP-CDP stacks. a) Straight fibre, b) Geophones.

The stacked sections were compared with an inline of the 3D seismic baseline acquired in 2014 that crosses the observation well 2. Figure 5 shows the comparison of the processed DAS and geophone data with the surface seismic data. Both, DAS and geophone stacked sections effectively display the target of interest and show a good correlation with the surface seismic data.

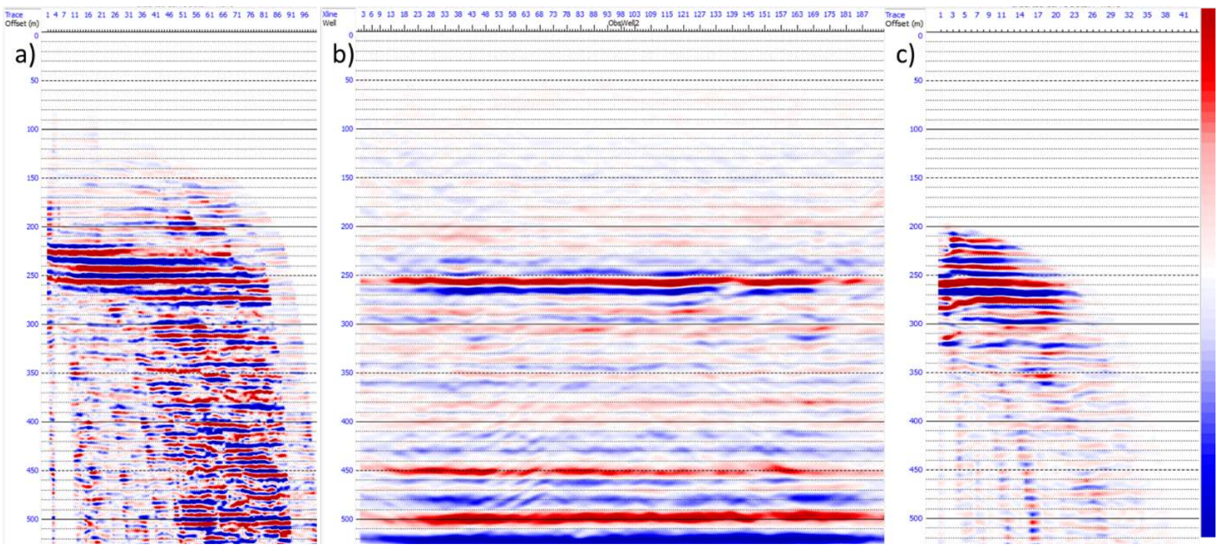

Figure 5. Stacked sections compared to surface seismic. a) Straight fibre, b) surface seismic data, c) geophones.

Overall, the processed datasets yield a good imaging result that can be correlated to surface seismic data. The event of interest was identified in each dataset and it also matched the surface seismic. DAS dataset also shows more seismic events in the shallow section that could be helpful for further studies of the overburden section.

Conclusions

A walk away VSP line was processed while performing a thorough comparison between the DAS and geophone datasets. A good correlation between the DAS and geophone datasets was obtained. Having a full coverage of the fibre optic cables in the well yields better imaging results in the shallow section. A clear identification of the CO_2 injection target was achieved for the straight fibre and the geophones.

The stacked sections also show a good correlation with an inline from a 3D surface survey passing through Observation Well 2. This comparison gives us a positive effect on DAS applications for subsurface imaging while encouraging us to continue the study of DAS measurements.

Acknowledgements

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