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Field test of DAS fibre-loops for surface-based seismic surveys

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Summary

Surface-based seismic field data were acquired at the Aquistore CO_2 storage site through DAS measurement using a tactical fiber-optic cable deployed in vertical loop configurations. The objective of this test was to assess the capability of DAS fibre-loops for large-scale surface-based seismic imaging. Initial P-wave reflection imaging results of the DAS data compare very well with geophone data that were acquired concurrently. Seismic reflections, generally, seem more coherent in the DAS data than in the geophone data, indicating the capability and potential of DAS-fibre loops for cost-effective surface seismic surveys in such environments.

Introduction

Distributed acoustic sensing (DAS) is an emerging seismic acquisition technology that utilizes optical pulses in fiber-optic cables to measure strain or strain rate along the fiber (e.g., Lindsey and Martin, 2021). DAS is routinely used for acquiring vertical seismic profiles (VSP) in wellbore deployments (e.g., Hartog et al., 2014; Mateeva et al., 2014; Daley et al., 2016; Harris et al., 2016). The fibre-parallel strain sensitivity of DAS fibers makes them well-suited for this purpose and the focused attention on DAS-VSP research has greatly improved its utility. In contrast, surface-based deployments of horizontal fibers have low sensitivity to steep angle P-wave reflections making DAS less directly suitable for surface-based seismic imaging. Attempts to improve DAS sensitivity for surface surveys have concentrated largely on helical configurations that increase sensitivity. Due to the complexity of DAS systems, this remains an active area of research and has the potential to benefit the seismic exploration industry. The ability of current DAS interrogators to record signals over tens of kilometres increases the potential usefulness of such deployments.

A variety of experimental fibre configurations were tested at the Aquistore CO_2 storage site in 2020 (White et al., 2022). Of these, vertical fibre loops deployed in shallow (3m) drillholes produced reflections observed on raw shot gathers that were comparable to data recorded by buried geophones. We further explore the utility of this deployment configuration through a large-scale field test that was implemented at the Aquistore site in November-2023. The goal of this test is to process the DAS fibre and geophone data to final image for a direct comparison. This will allow an objective assessment of the capabilities of surface-based seismic imaging using DAS in this environment and its potential for long-term monitoring in CO_2 storage projects.

Fibre Deployment and Data Acquisition

In November-2023, a full 3D dynamite seismic survey was acquired at the Aquistore site using spatially coincident DAS fibre vertical loops and geophones. A total of 8000 m of tactical fibre-optic cable was buried at 80 cm depth along 6 receiver lines of an existing permanent geophone array at the site. The fibre forms a continuous run with 3 m vertical loops installed adjacent to the geophones along the line for a total of 95 spatially coincident fibre loops and geophones (Figure 1). The Geological Survey of Canada (GSC) Onyx sensing unit was connected to the fiber to form the DAS recording system, which comprised all channels from the interrogator to – end of cable – back to interrogator. Over 370 dynamite shots (at charge depth of 15 m) with shot spacing and line interval of 144 m and 288 m, respectively, were recorded with the fibre and geophones concurrently. The geophone data were recorded with receivers buried at 20 m and a receiver spacing of 72 m, while the DAS data were recorded with a channel spacing that is equal to the gauge length of 4.8 m.

Data Processing

Shot records of the DAS data show the vertical loops as high amplitude streaks corresponding to 2 or 3 consecutive channels. The channels were stacked so that each vertical loop matched exactly 1 channel, and the DAS data were then converted from the spatial differential of phase to particle velocity to provide a response that is comparable with the geophone's response. The vertical loop DAS channel coordinates were inherited from the geophones whose location coordinates are well known. These steps were followed to ensure the datasets (DAS and geophone data) are consistent and allow for standard seismic data processing to be applied to the DAS data. Figure 2 shows a comparison of raw shot gathers for geophone and DAS vertical fibre-loop data. Overall, the DAS data compare very well with the geophone data. The DAS and geophone raw data were processed in parallel as low-fold 3D seismic data using standard seismic data processing procedures comparable to those applied to previous data acquired at the site (e.g., Roach et al., 2017). These procedures include spherical divergence (t^2 amplitude scaling), elevation statics correction, surface-consistent spiking deconvolution, bandpass filtering, refraction statics correction, normal move-out, automatic gain control, common-depth point (CDP) stacking and bandpass filtering.

Data Assessment and Conclusions

The CDP stack sections shown in Figure 3 are results for both datasets after applying the processes above. To assess the performance of DAS fibre-loops for surface seismic surveys, initial imaging results of the DAS data were directly compared with that of the geophone data. Since most of the P-wave reflections arrive after ~800 ms, comparison of the CDP stack sections was mainly focused between 700 ms and 2000 ms. In general, the DAS fibre-loops data compare very well with the geophones data. For example, selected reflectors (R1 – R5) are all clearly imaged and appear reasonably coherent in both datasets. Some of the reflectors (e.g., R3 and R4) seem noticeably more coherent in the DAS fibre-loops data. In conclusion, these initial results indicate that DAS fibre-optic cable deployed in vertical loops can deliver seismic data comparable to data acquired with geophones in a large-scale surface-based survey.

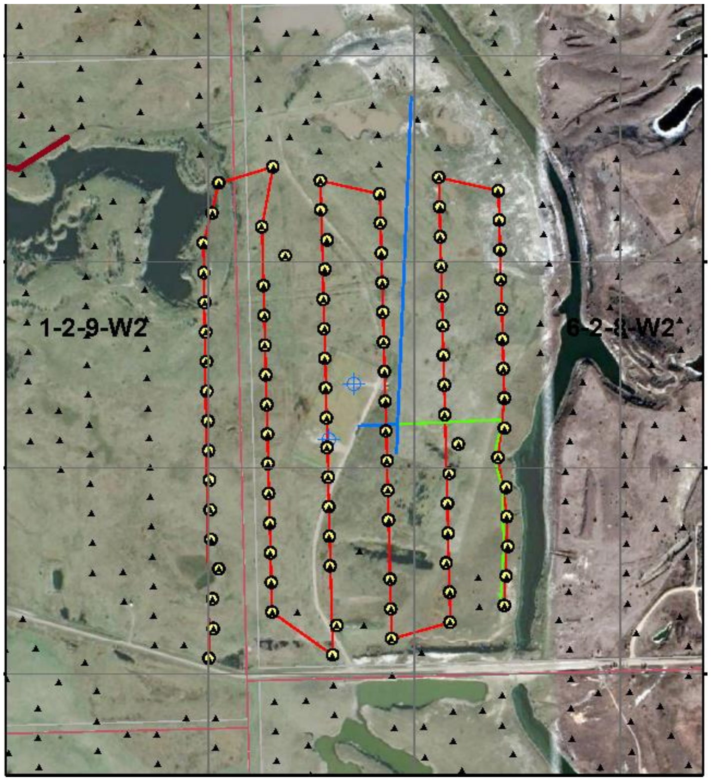

Figure 1: Location of the fibre cable deployed along the permanent geophone lines with 3 m vertical loops deployed at each of the geophone locations.

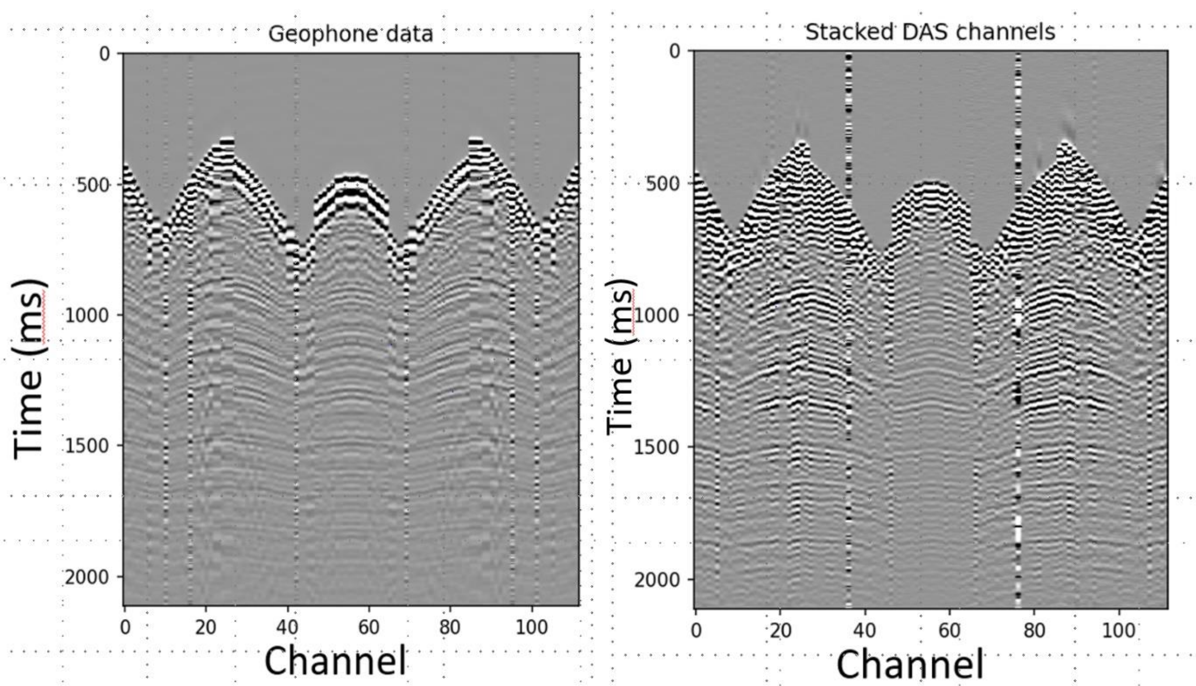

Figure 2: Raw shot gather data for geophones (left) and DAS fibre-loops (right). Each DAS vertical loop is adjacent to a buried geophone (see Figure 1) and data is from the same shot record.

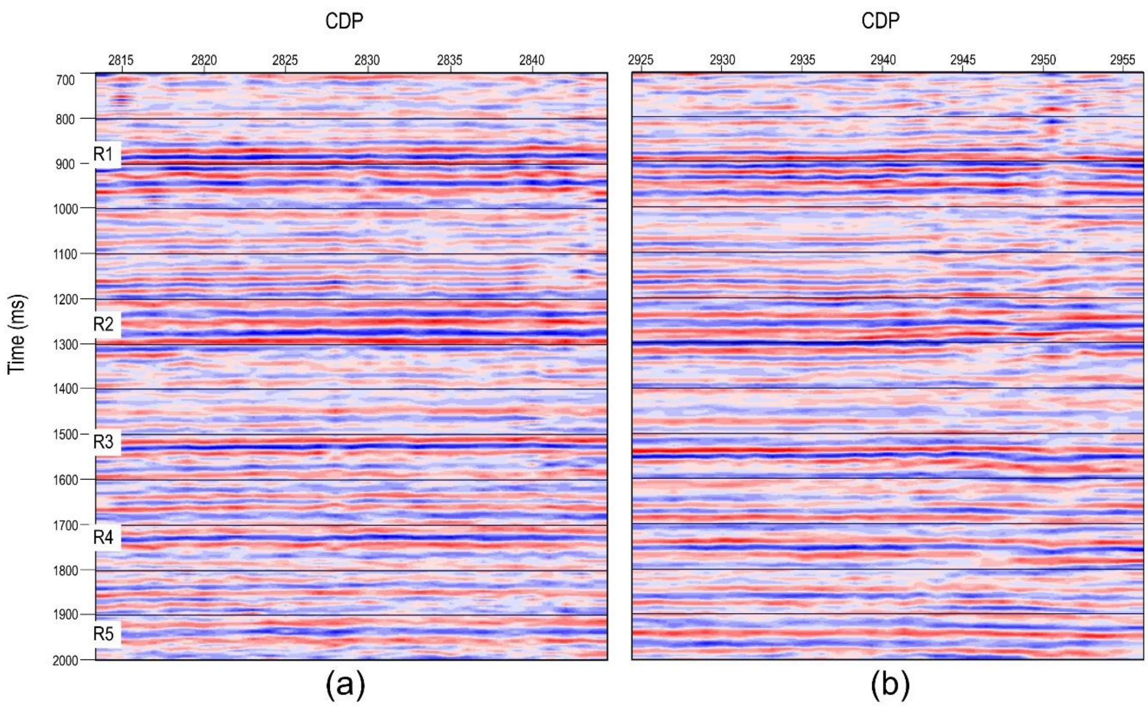

Figure 3: CDP stack sections after processing: (a) DAS fibre-loop data (b) Geophone data. R1 – R5 represent selected reflections.

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