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A nine-component seismic survey using experimental multi-component fiber sensors

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Summary

Seismic acquisition at Carbon Management Canada's Newell County Field Research Station was conducted in September and October 2024. Various seismic sources (P-Vibe, SH-Vibe, SV-Vibe, P-weight drop) were recorded on multiple lines using multicomponent downhole geophones, straight and helically wound optical fiber cable, and the Pretzel and the Croissant experimental directional optical fiber sensors. Preliminary nine-component Distributed Acoustic Sensing (DAS) data from the Pretzel and Croissant will be presented.

Introduction

The “Pretzel” eight-component fibre sensor was installed at Carbon Management Canada’s Newell County Field Research Station in 2018 (Innanen et al., 2019). The design includes two 10 x 10 m squares of fibre cables buried at 2 m depth. It is impractical to install a 10 x 10 m vertical component as part of the Pretzel. The “Croissant” three-component sensor was designed in 2023, and three of them were buried on site with the horizontal component about a meter below the surface, and the top of the vertical component just below the topsoil (Hall et al, 2024). The design is similar to one presented by Takekawa et al. (2022). Each Croissant consists of two 1 x 1 m plastic frames wrapped with fibre-optic cable. Note that the sides of the Pretzel are longer than our typical 7 m DAS gauge length, but the sides of the Croissant are significantly shorter. Surveys in 2024 recorded data using various sources and instruments, including the Pretzel and Croissant sensors. Figure 1 shows a map of the September 2024 survey layout. Line 41 was acquired using a P-Vibe. Lines 15 and 55 were acquired using P-, SH-, and SV- mode Vibes. Figure 2 shows a map of the October 2024 survey layout. All lines were acquired using a P-Vibe. Additionally, line 200 was acquired using a P-mode accelerated weight-drop source.

Preliminary Results

Line 41: Compaction Experiment

The Pretzel and Croissant sensors rely on soil compaction for coupling. Line 41 was acquired the day after the Croissant was buried in 2023 and re-acquired in 2024 to assess data quality improvement due to a year's worth of soil/clay compaction. The 2024 data appear to have a better signal-to-noise ratio at greater travel times. This effect is more prominent on the vertical component data.

Line 15: Nine-component experiment

A shortened line 15 was acquired with 4 sweeps per Vibe Point (VP) using a 16-second long 10-150 Hz sweep with 4 sweeps per VP using a P-Vibe, and a 16-second long 10-100 Hz sweep with 6 sweeps per VP using a S-Vibe that was operated with the mass vibrating inline (SV-mode)

and crossline (SH-mode). A S-Vibe source-effort experiment was conducted at VP 15168. A permanent sparker source is located about 10 m from the Pretzel on the opposite side of Line 13 (Figure 1). It wasn't operational, but an air compressor nearby ran unexpectedly for 30 seconds every 2.5 minutes on the morning of September 26th, contaminating some SH-Vibe data with 57 Hz noise. This noise can be used to locate the Pretzel on line 13 fiber data. Stacked and correlated receiver gathers from a single Croissant sensor for data acquired on September 25th and 26th are shown in Figure 3. Comparison of Pretzel and Croissant receiver gathers shows a similar qualitative character, regardless of the sensor size relative to the gauge length.

VP 55101: Rapid time-lapse VSP

Cai et al. (2023) present anomalies seen in elastic full waveform inversion results that can be related in time to reservoir pressure changes due to CO2 injection, using repeated vertical seismic profile data that were acquired at VP 55101 over the course of many days using a P-Vibe. VP 55101 was re-acquired in 2024 with multiple P-, SH-, and SV- sweeps over two days, while CO_2 was being injected into the reservoir.

P-Vibe and P-weight-drop Comparison

Comparison of Vibe data with 4 sweeps per VP, and weight-drop data 10m away on Line 200 with 30 hits per SP shows similar frequency content on the DAS data, but a higher signal-to-noise ratio for the Vibe data.

Future Work

Future work will involve comparisons of source-effort, source-type, and receiver type (directional fiber sensors, surface and borehole straight and helically wound fiber, and borehole geophone data). Processing will include, but is not limited to, a line 15 walk-away 9C VSP (geophone), line15 walk-away 3C VSP (DAS), and FWI of the rapid time-lapse VSP data.

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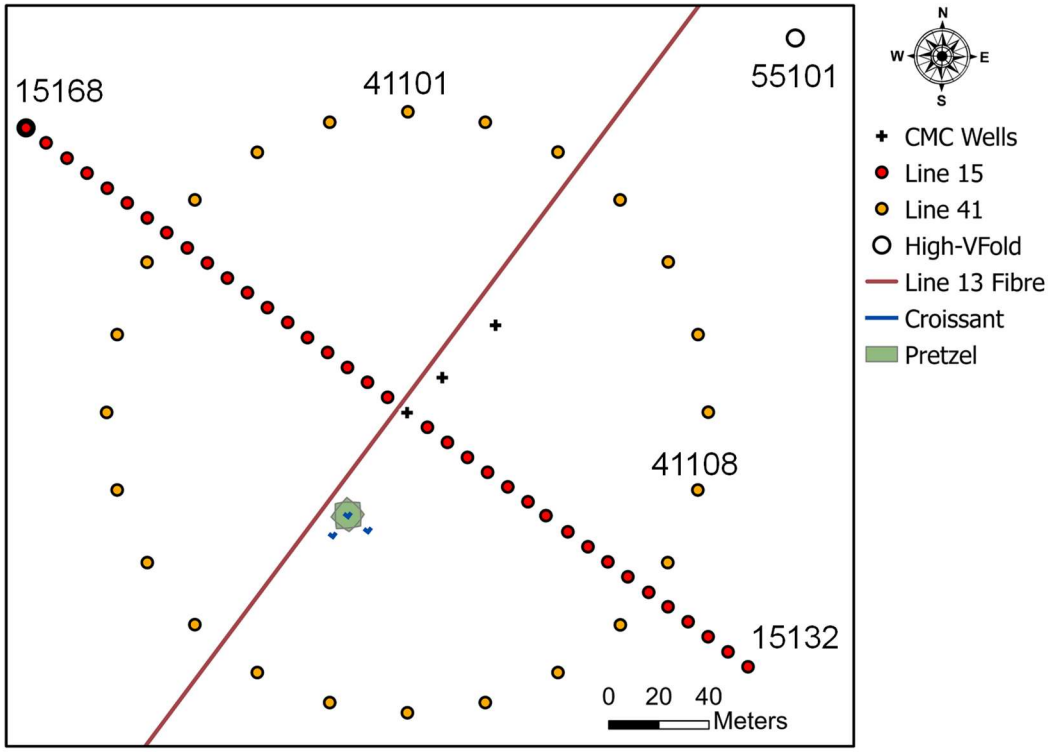

Figure 1. Map showing the September 2024 survey layout.

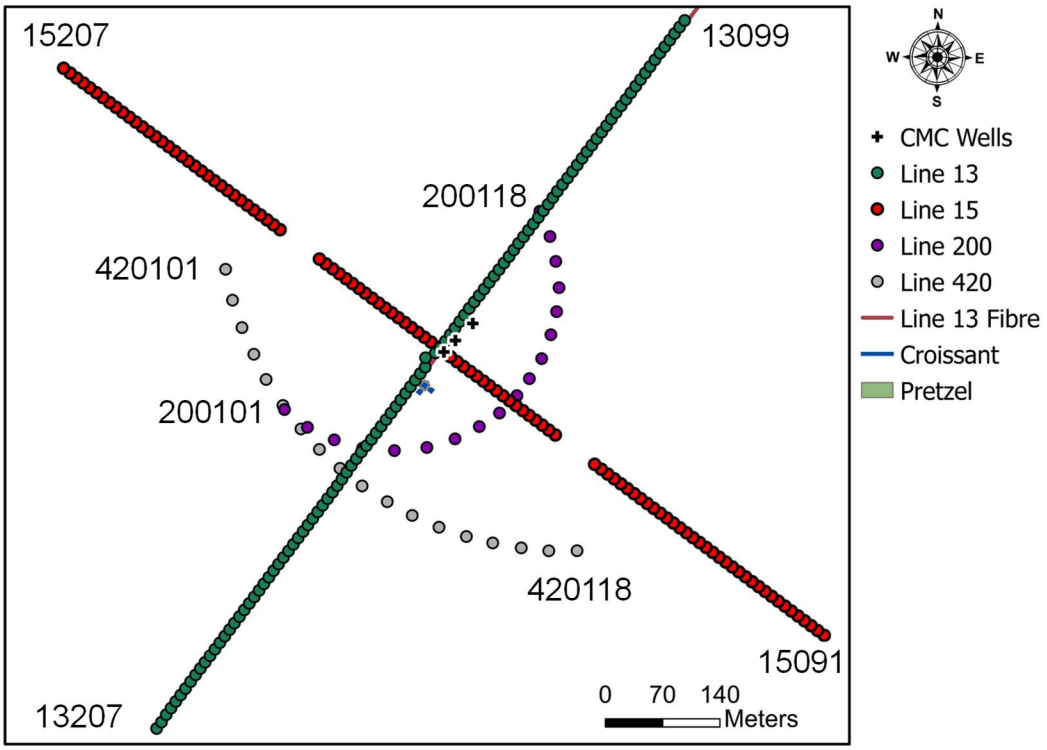

Figure 2. Map showing the October 2024 survey layout.

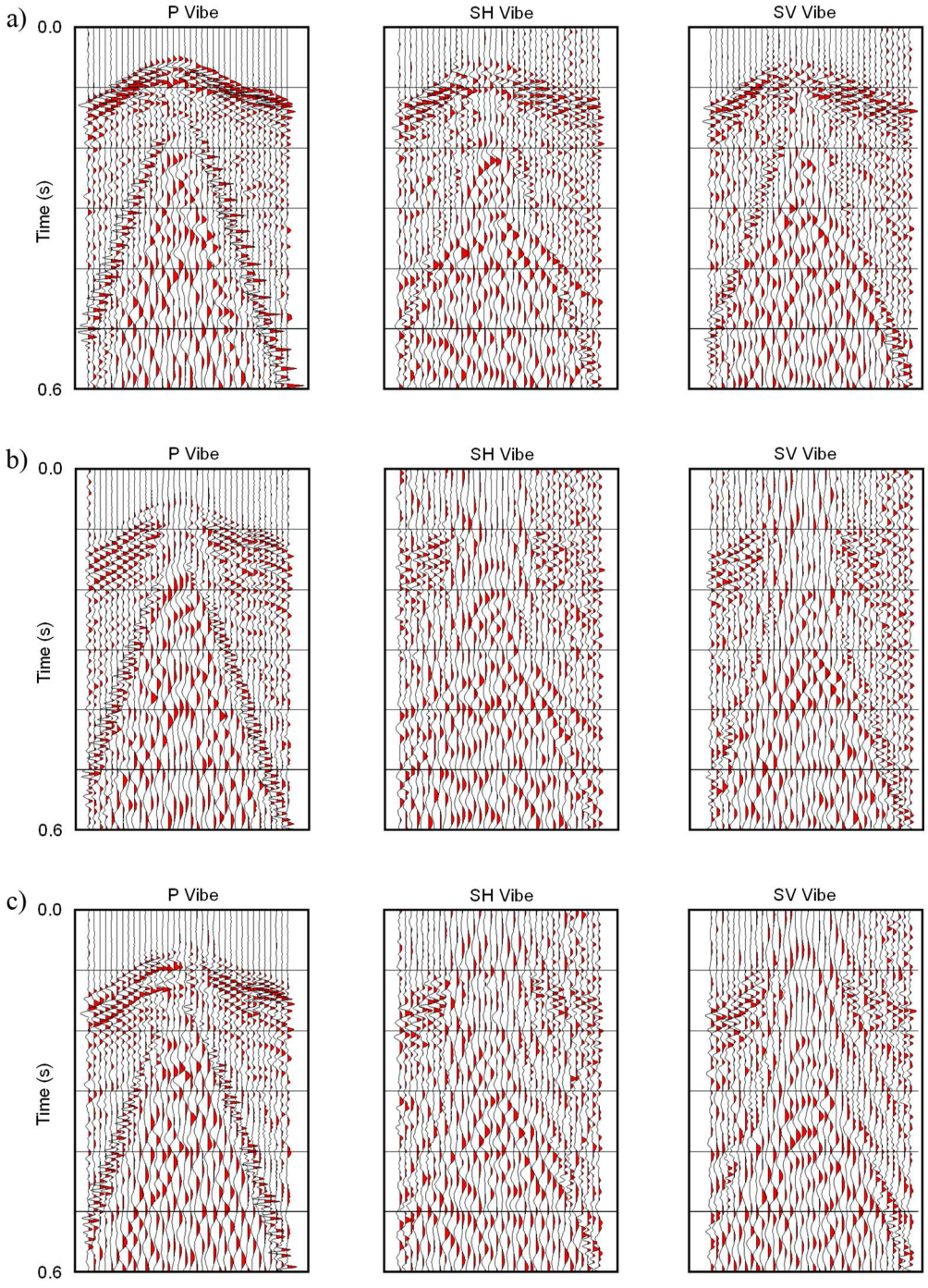

Figure 3. Line 15 Croissant 1 (C1) receiver gathers. C1-V (a), C1-H1 (b), C1-H2 (c).

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