# CCSMR Task 2: 2nd Generation SOV-DAS

**Project ESD14095**

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U.S. Department of Energy

National Energy Technology Laboratory

Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting

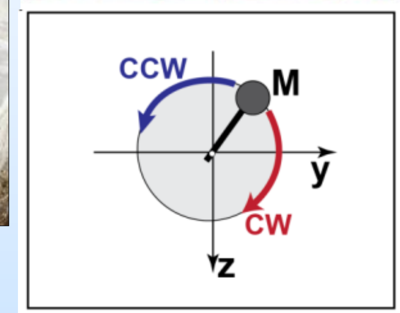
August 26-30, 2019

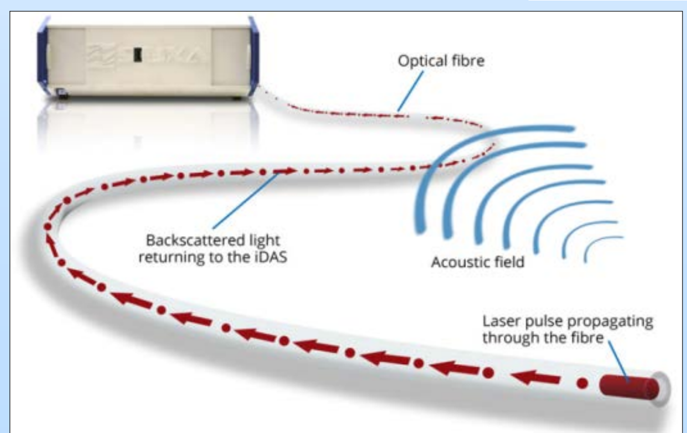
# Presentation Outline

- Motivation for SOV-DAS Technology
- SOV-DAS for monitoring
  - Otway Stage 3 multi-well VSP monitoring
  - Synergistic developments at ADM
- New SOV
  - Redesign (swept $S_H$ source)
  - Field trial of new technology - EFSL

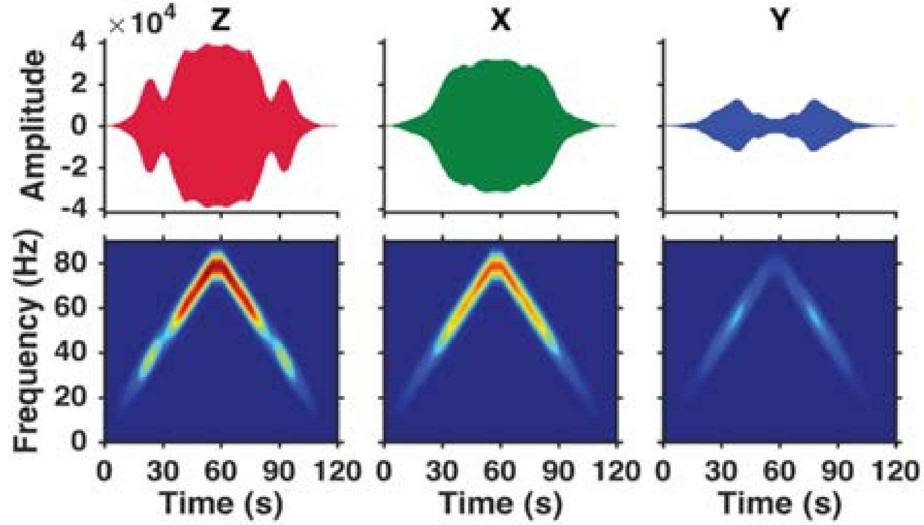
Conventional
campaign-based systems
small T, large N

SOV-DAS permanent monitoring system
large T, moderate N

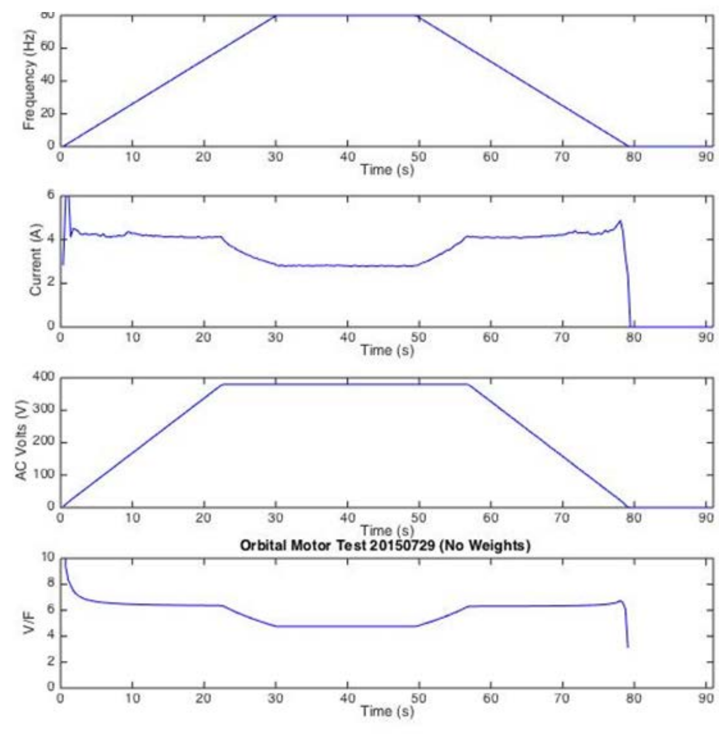
# Surface Orbital Vibrator (SOV) – Controlled AC Motor



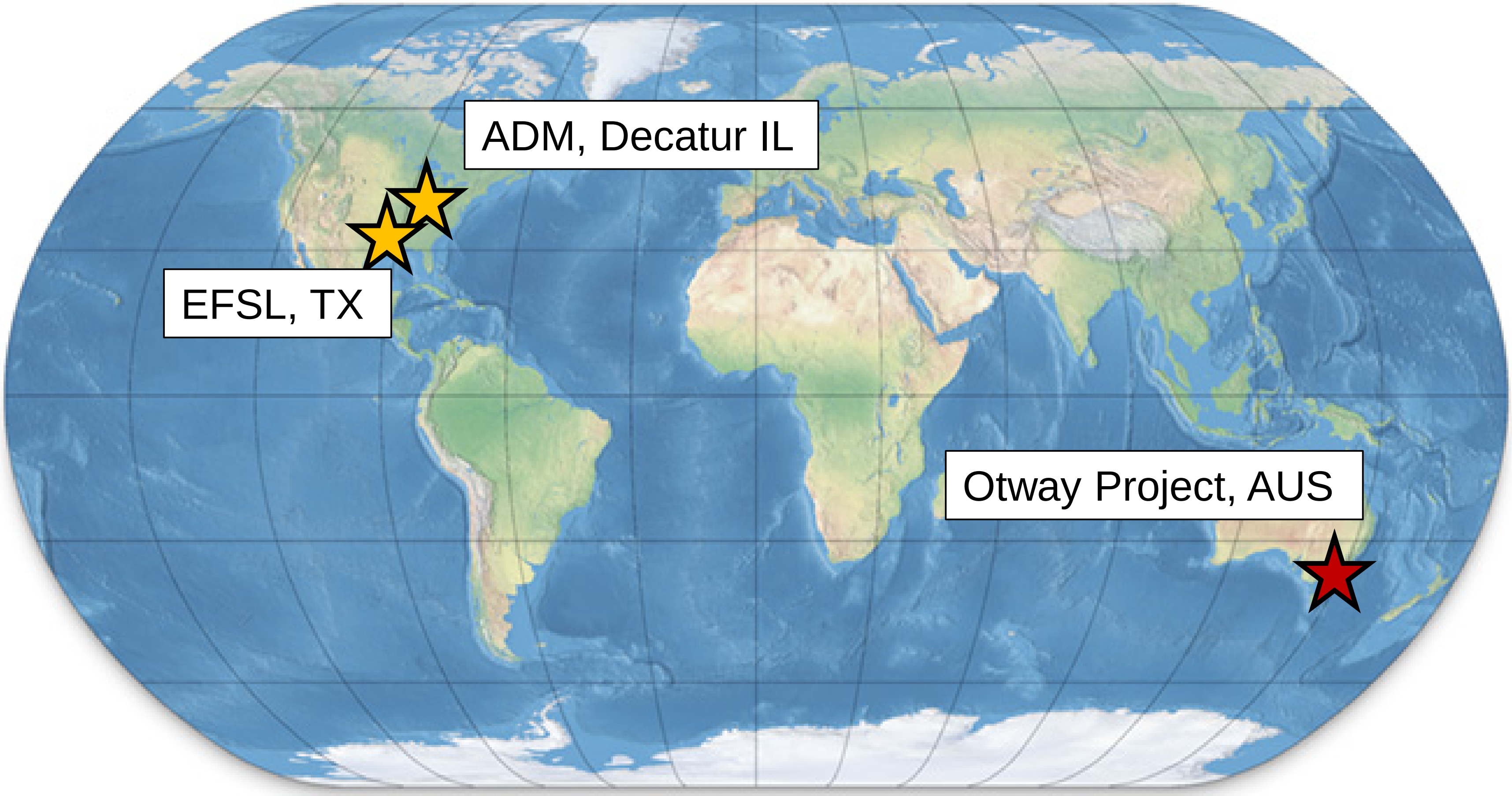

Max Frequency 80 Hz, Force (@80Hz) 10 T-f
Operate 2.5 hr/d

Force is adjustable

$F=m\omega^2 r$

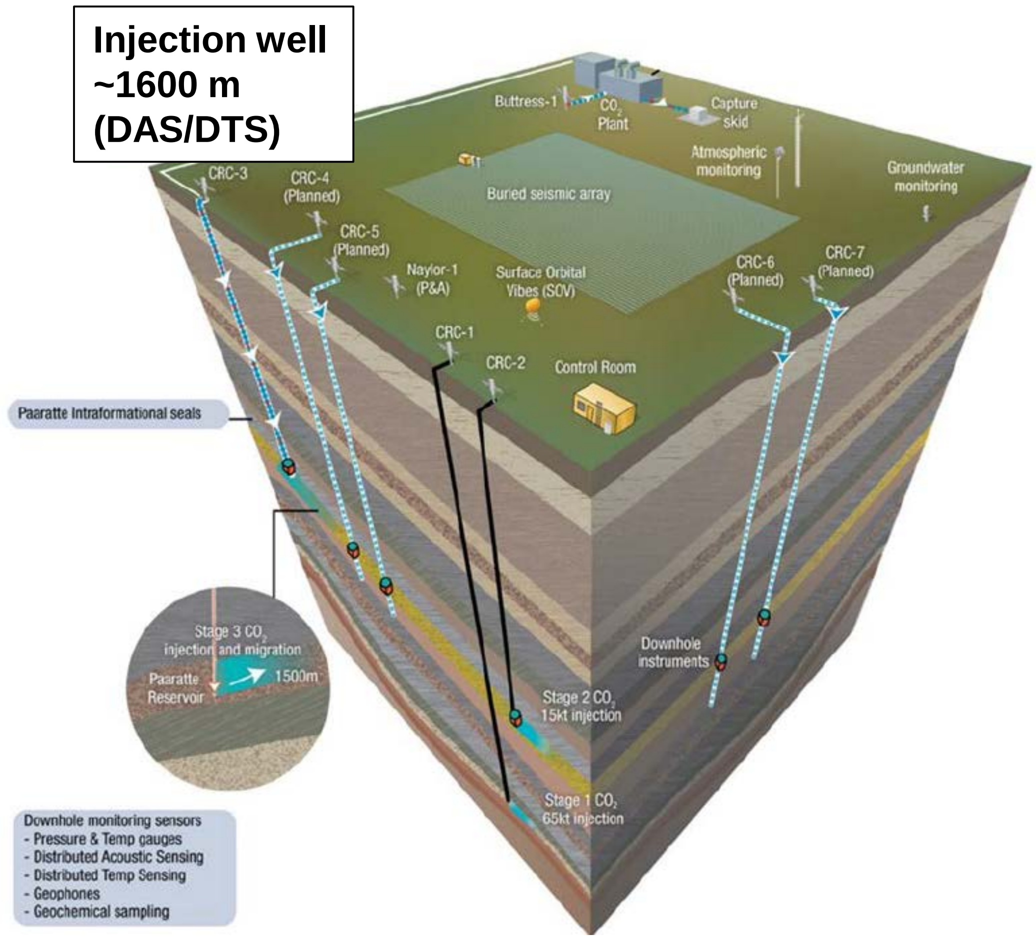


# DAS/SOV



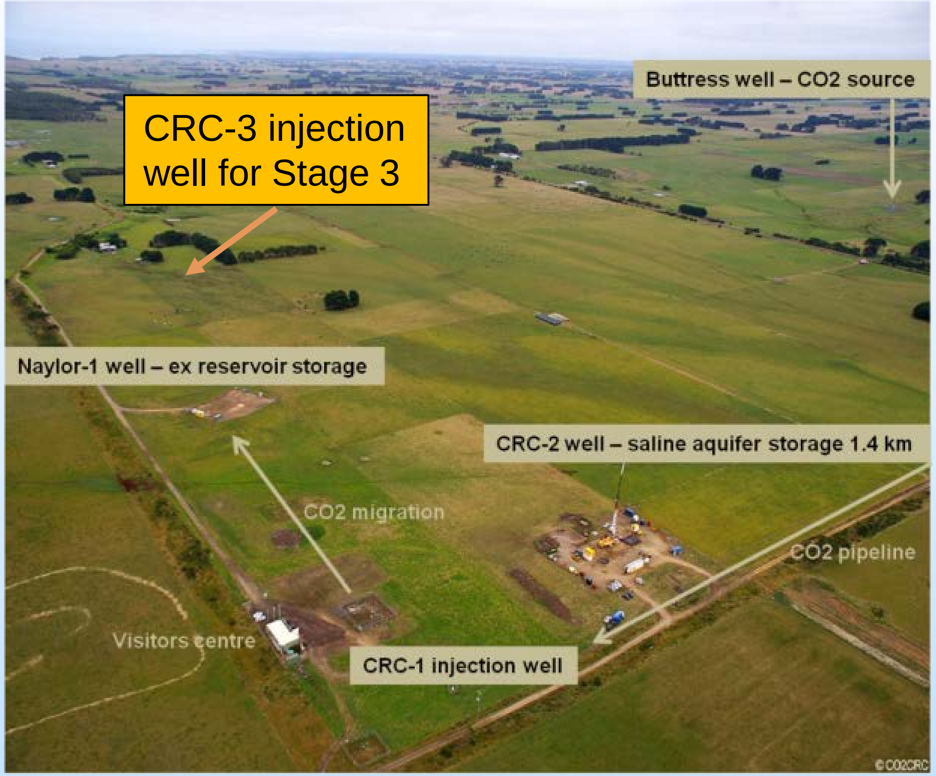
# Otway Project
# Stage 3 Concept

- Built on previous experience
- Multi-well seismic monitoring using 4D DAS VSP and SOV sources
- Seismic processing automation
- Reduction of cost and acquisition footprint

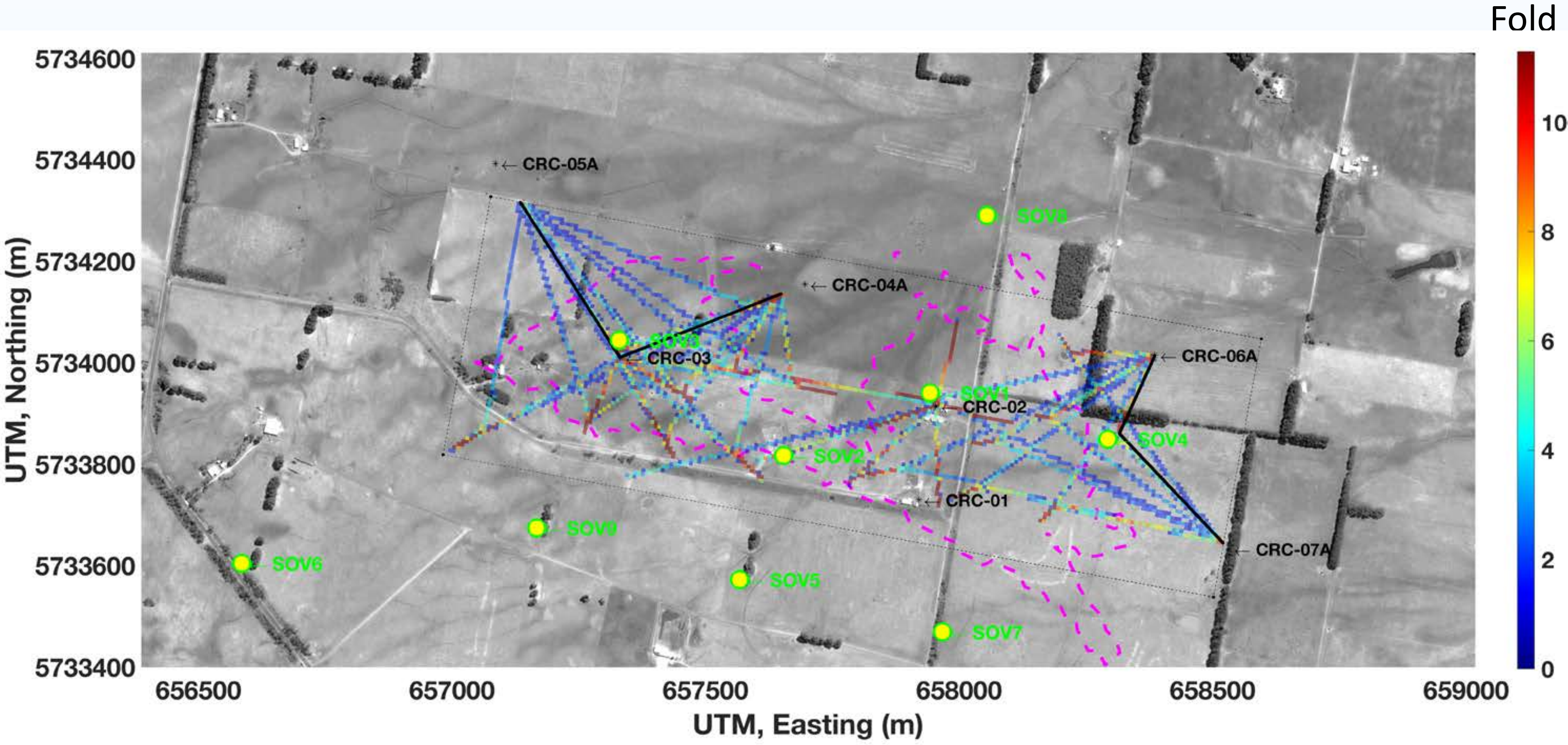


# Otway Project Stage 3

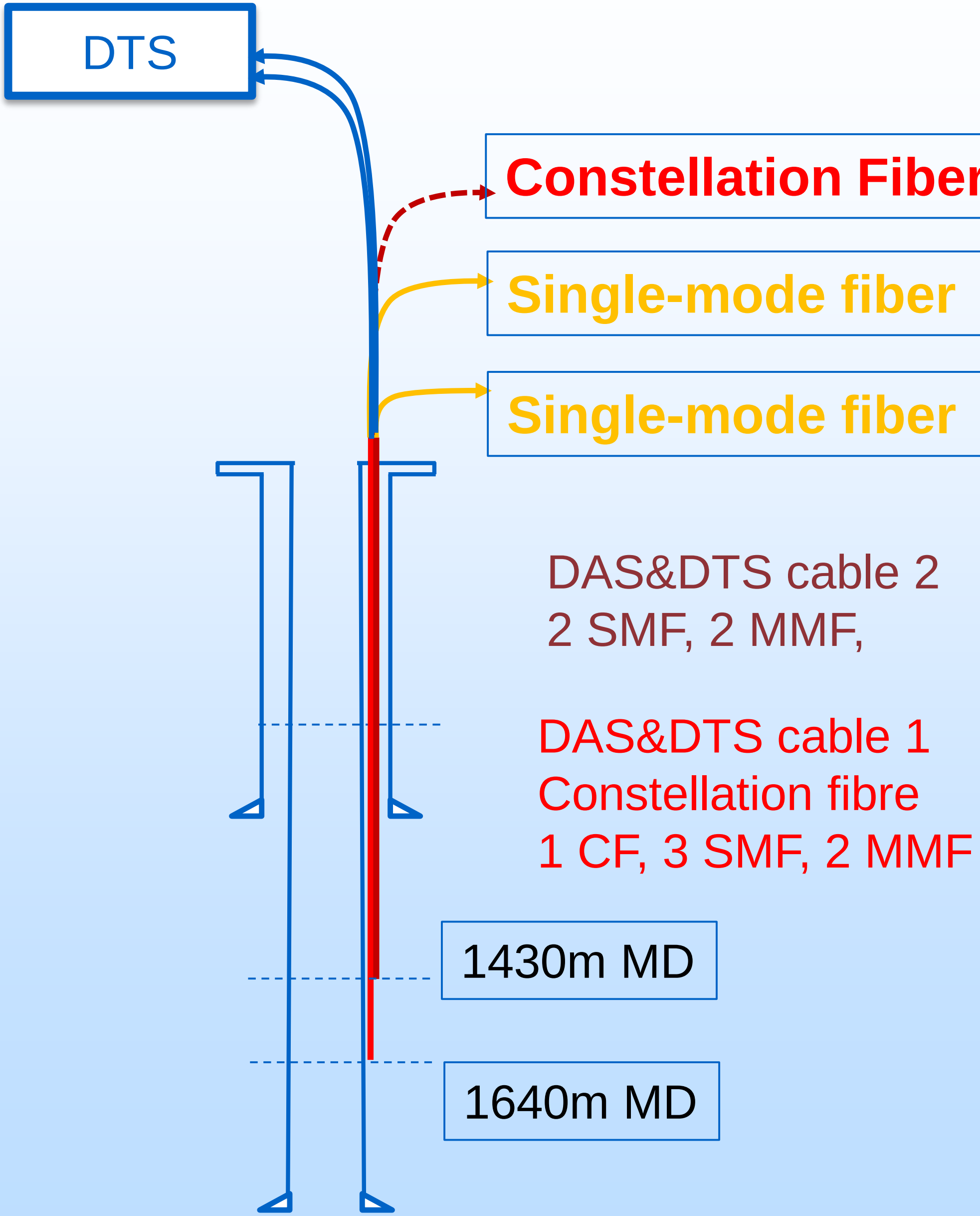
- Injection of 15 kt of supercritical $CO_2$
- Drill 4 wells at the CO2CRC Otway test site, to form a subsurface monitoring array
- CO2CRC purchased 7 new SOVs (9 in total) to be operated daily
- LBNL will install SOVs and provide technical support
- LBNL and Curtin University (Australia) will generate processing flows for daily 2D images of the $CO_2$ plume in subsurface



# Seismic coverage by 9 permanent sources and 6 wells instrumented with DAS



# CRC-3 well – injection well for Stage 3




- CRC-3 configuration
- Cable 1: Constellation fiber, single-mode, multi-mode
- Cable 2: single-mode, multi-mode

- 4 additional wells planned for October

# Field trials
## Optimizing SOV/DAS acquisition

Field trials for **testing optimal parameters** for SOV/DAS acquisition

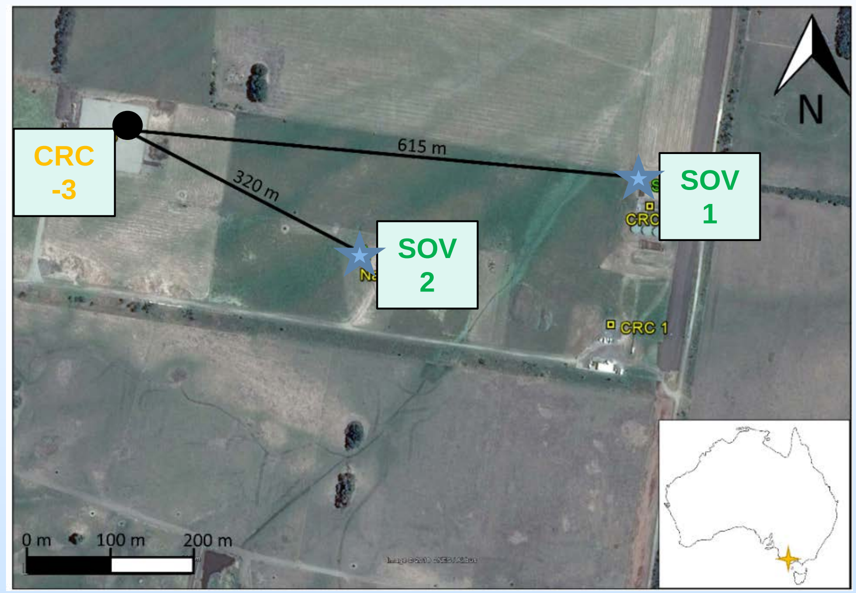
1- Engineered (Constellation) fiber vs Conventional (single-mode) fiber

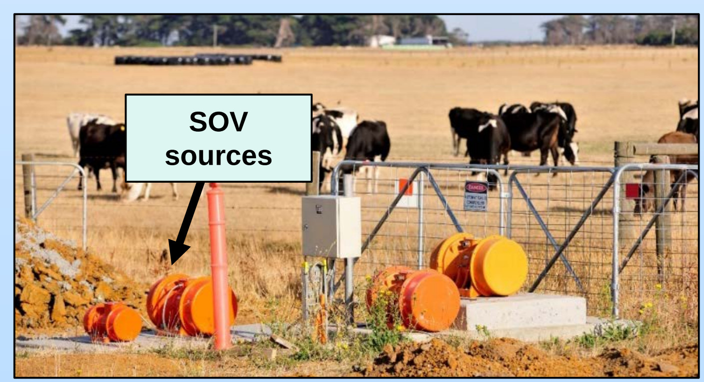
2- Different motors and sweep frequencies on conventional fiber

3- Different motors and sweep frequencies on engineered fiber

# Conventional SMF vs Constellation (May 2017)

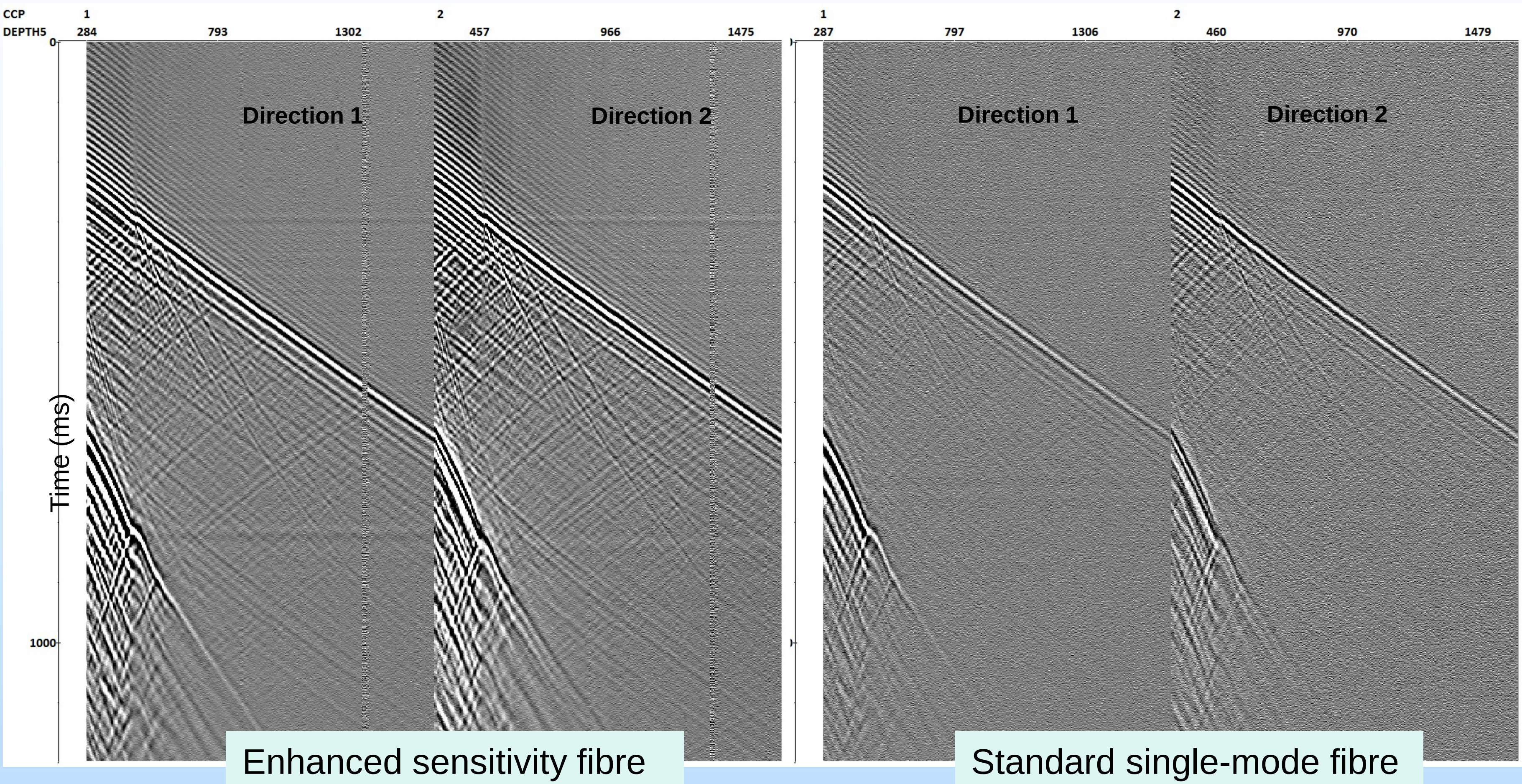
- Sweep design:
  - Up to 80 Hz
  - ~10 t force at 80 Hz
  - 150 s sweep (30 s upsweep, 120 s downsweep)
- 14 sweeps stacked in each direction



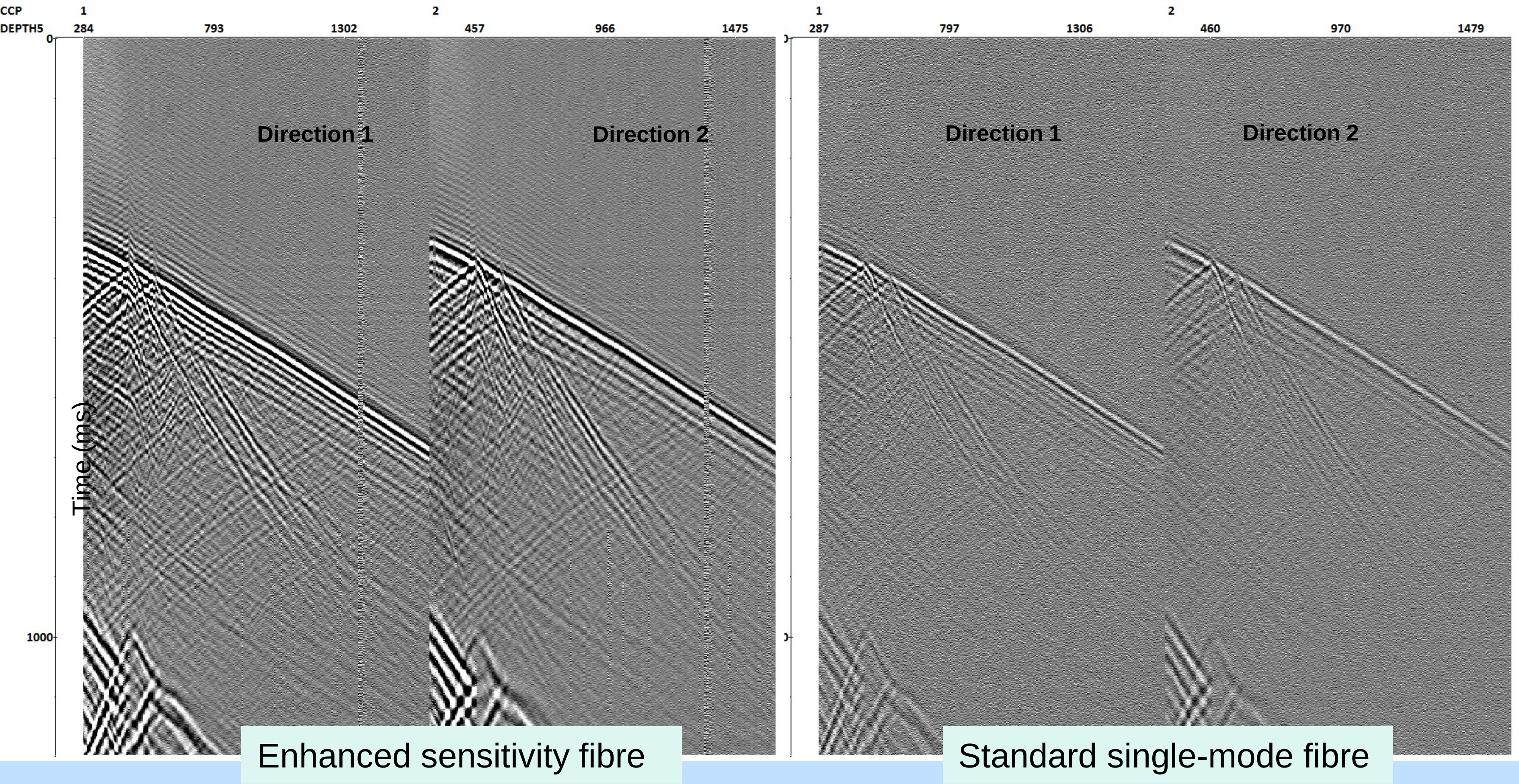
# Conventional SMF vs Constellation (May 2017)

*SOV 2 (150 s to 80 Hz sweeps), stack 14 sweeps*



# Conventional SMF vs Constellation (May 2017)

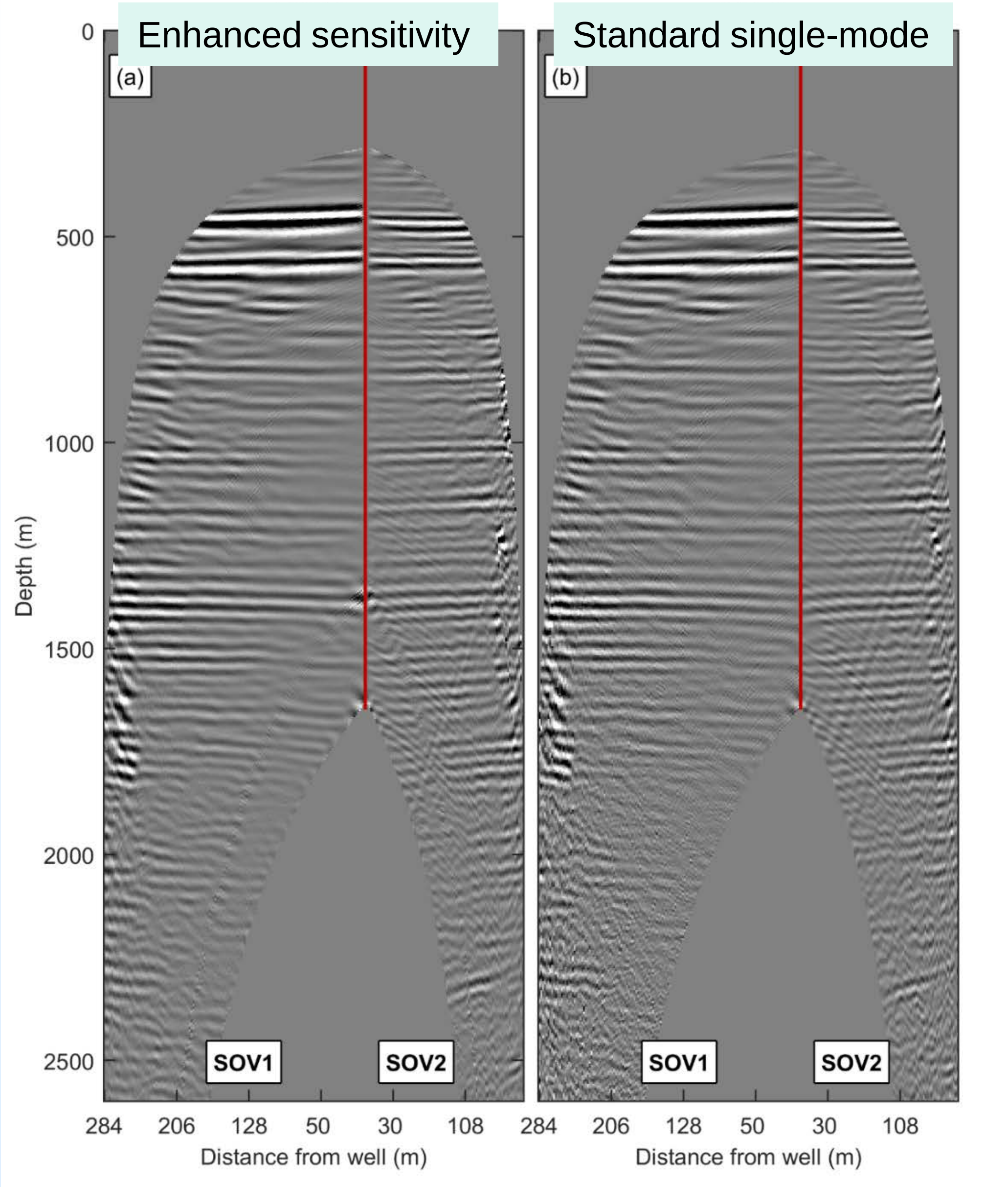
*SOV 1 (150 s to 80 Hz sweeps), stack 14 sweeps*



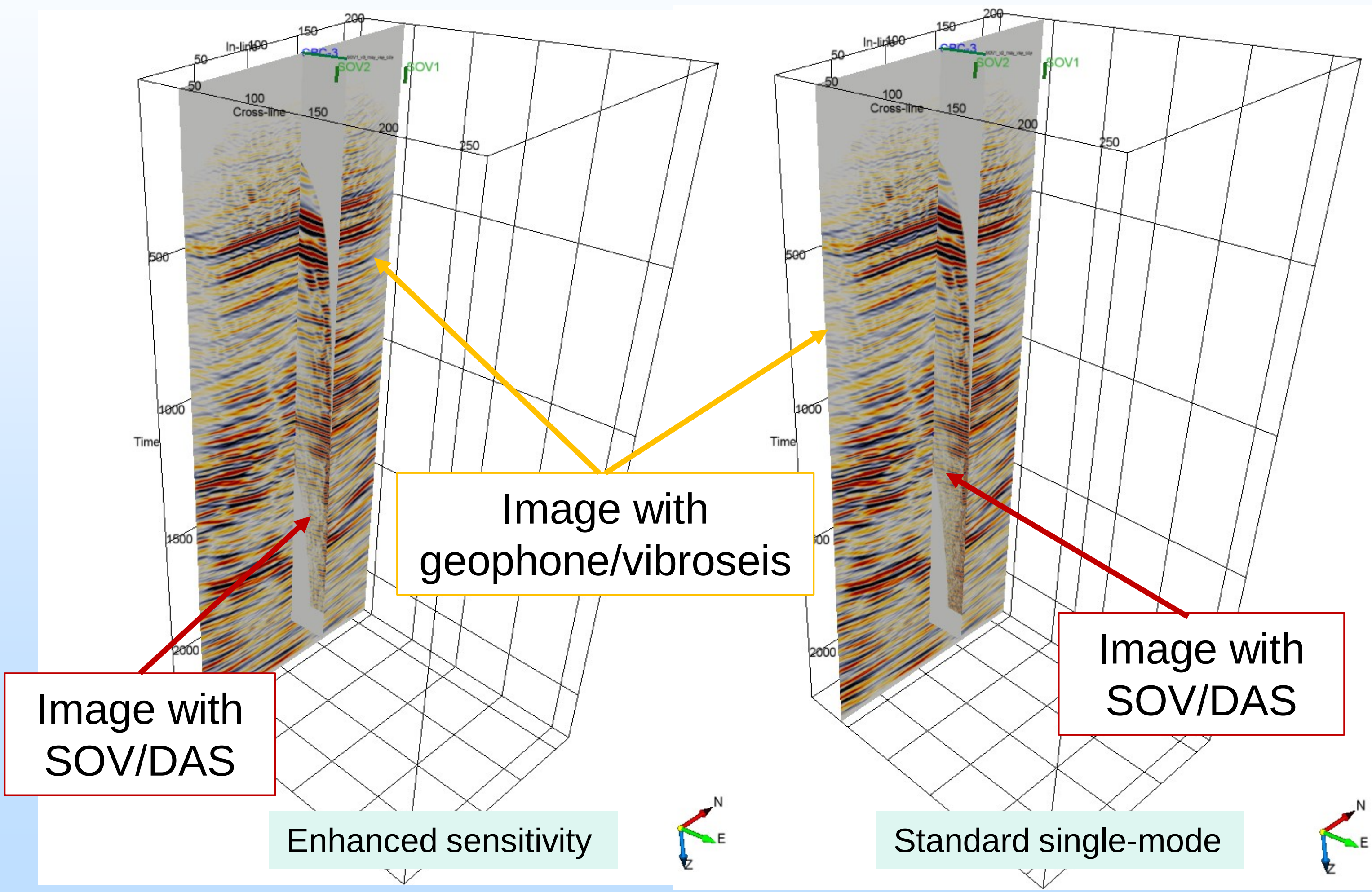
# 2D line from SOV/DAS records

- VSP to CDP transform of SOV/DAS records

- The 2D line correspondent to SOV1 and SOV2 are displayed side by side. Well path displayed in red.



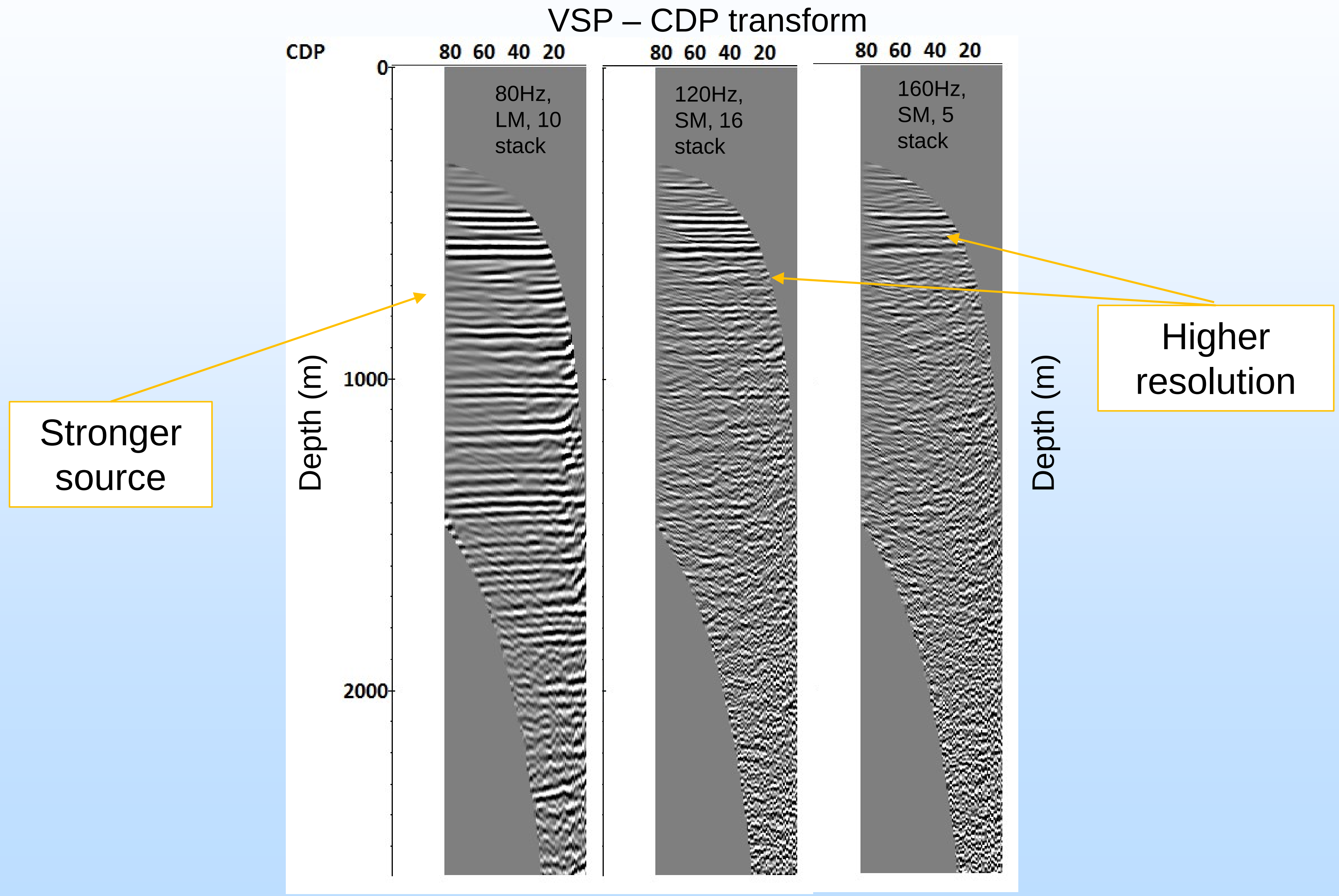
# Comparison of SOV/DAS with conventional (geophone) technology



# Performance of small and large motors: field trial in November 2017


| November test | |
|---|---|
| SOV 1 | SOV 2 |
| Large motors 0 – 80Hz | Large motors 0 – 80Hz |
| Small motors 0 – 120 Hz; 50% peak force | Small motors 0 – 120 Hz; 50% peak force |
| | Small motors 0 – 160 Hz; 50% peak force |

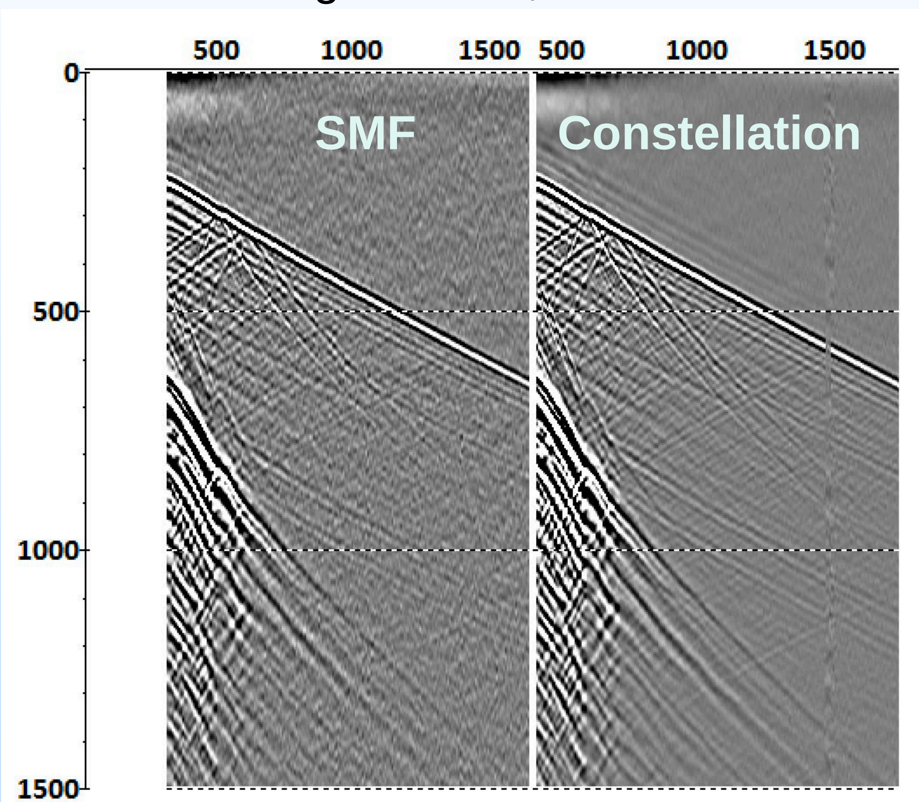
# DAS VSP (standard fibre) and SOV 2



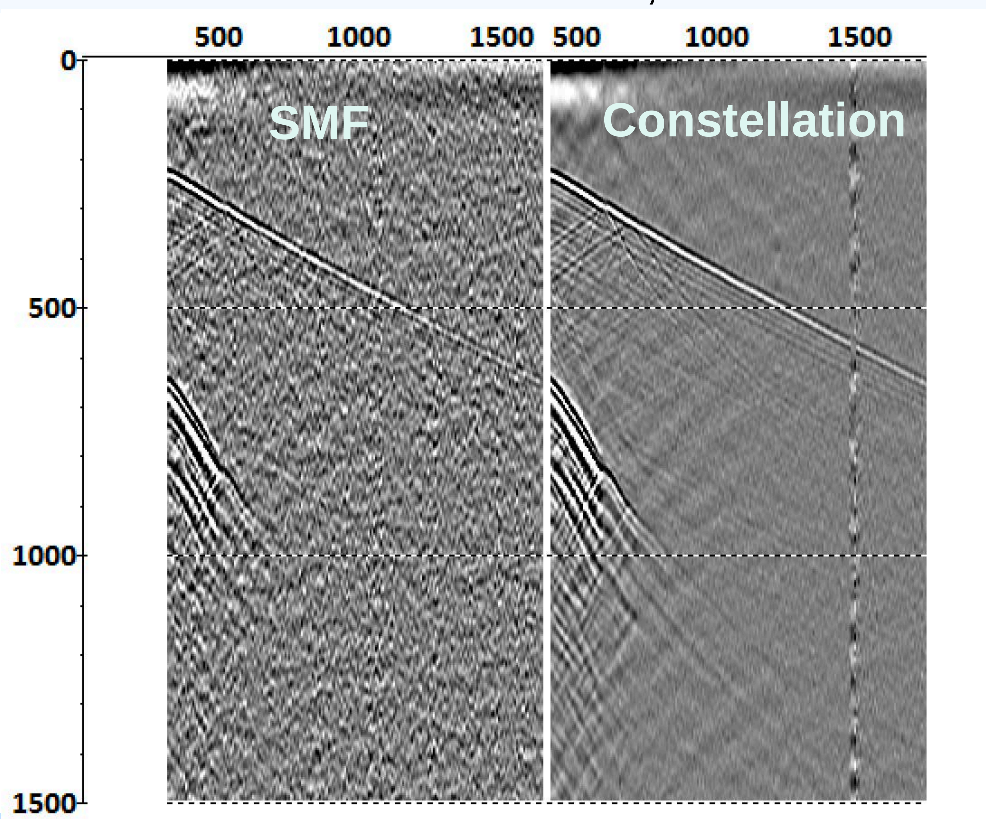
# Engineered fiber would allow to use combination of small and large motors

## Stack of 9 sweeps

Large motors, 0-80 Hz

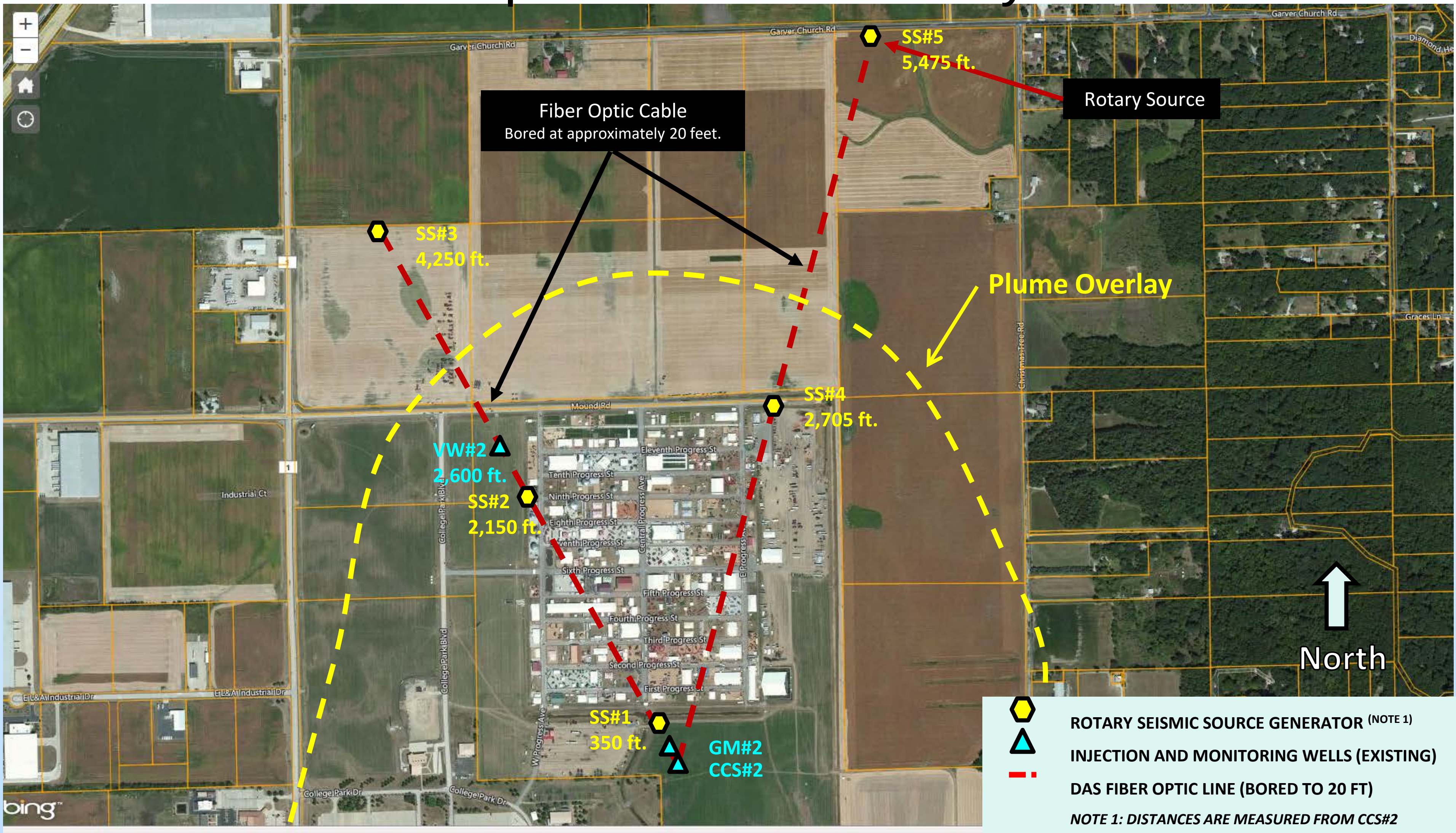



Small motors, 0-120 Hz

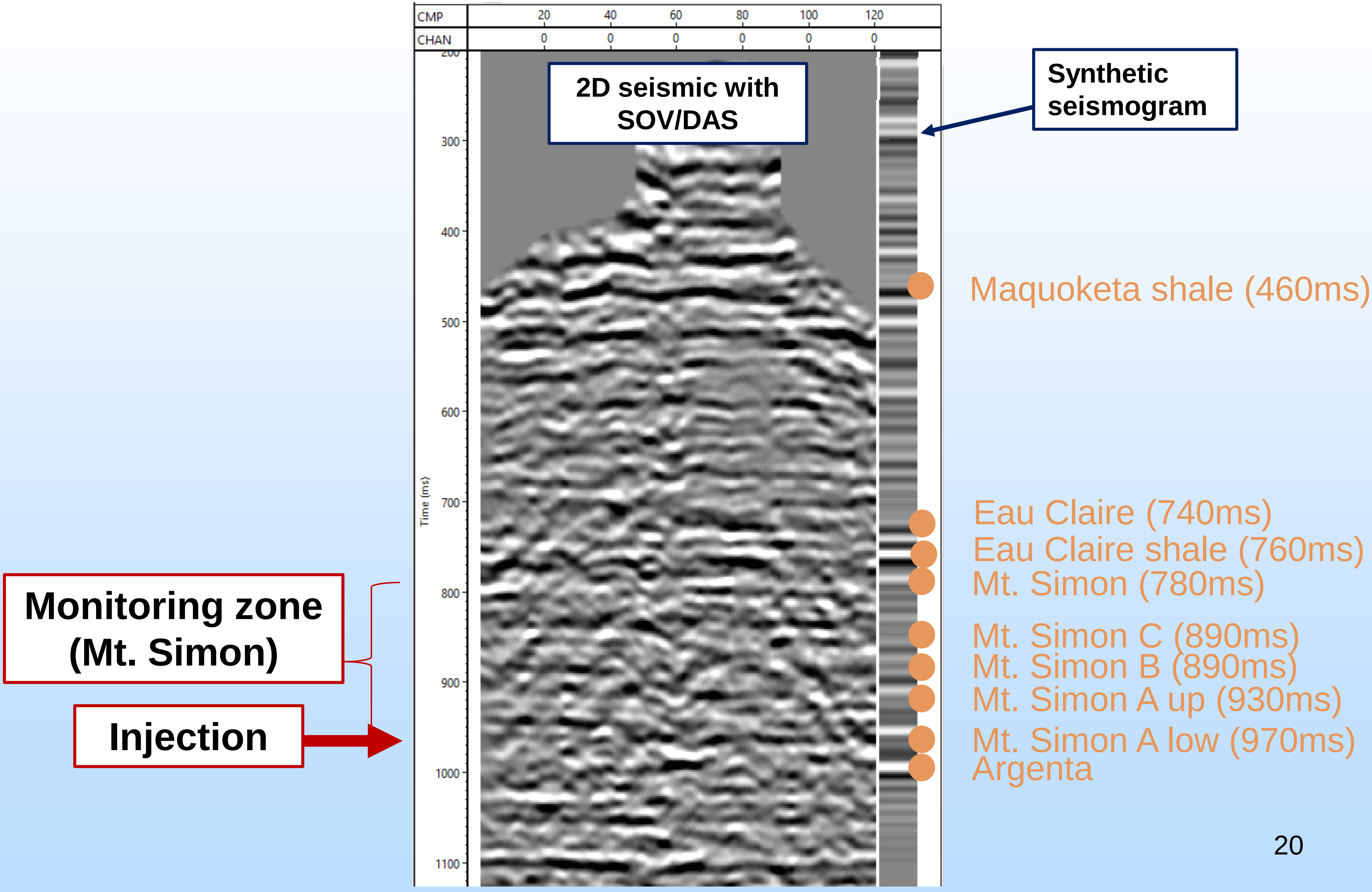


# ADM IMS Project

## Fiber Optic and CASSM Layout



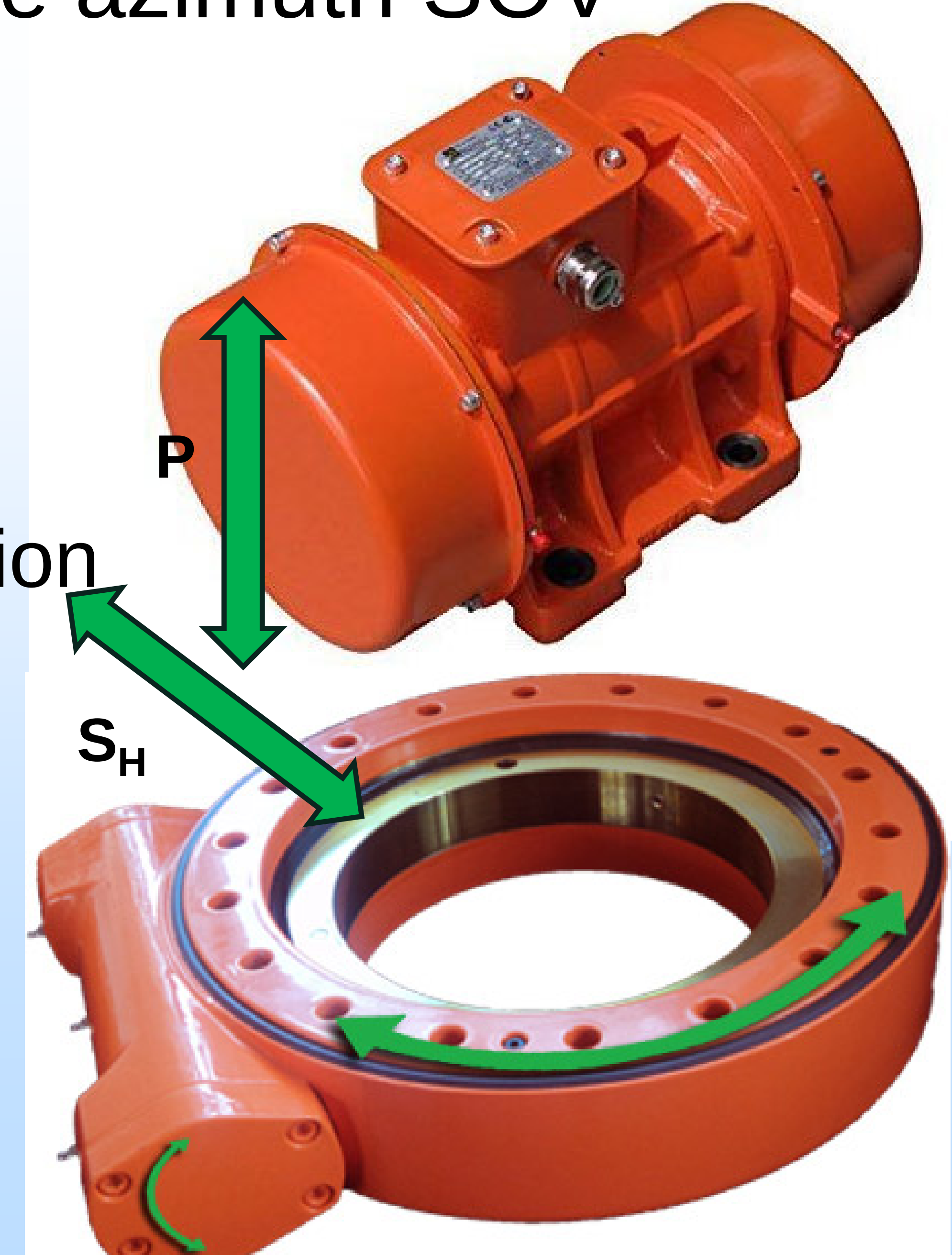
# Engineered fiber can allow for imaging deep reflectors when using surface cables



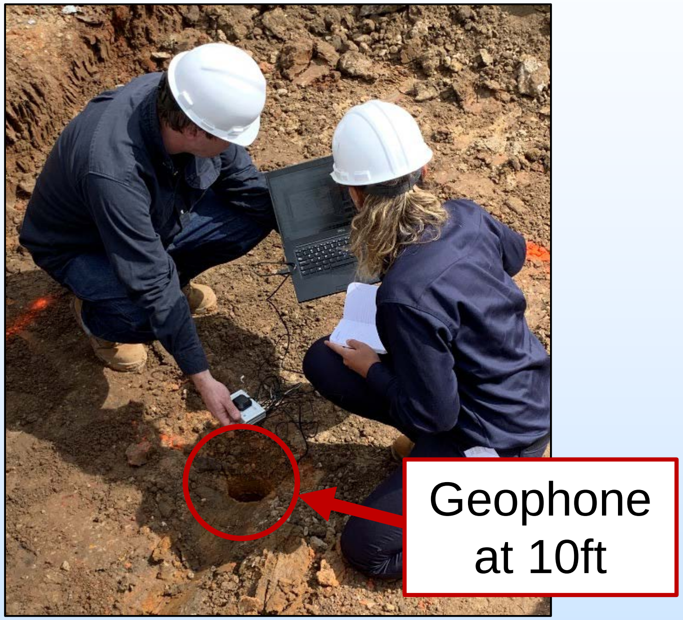
# Variable azimuth SOV

NEW!

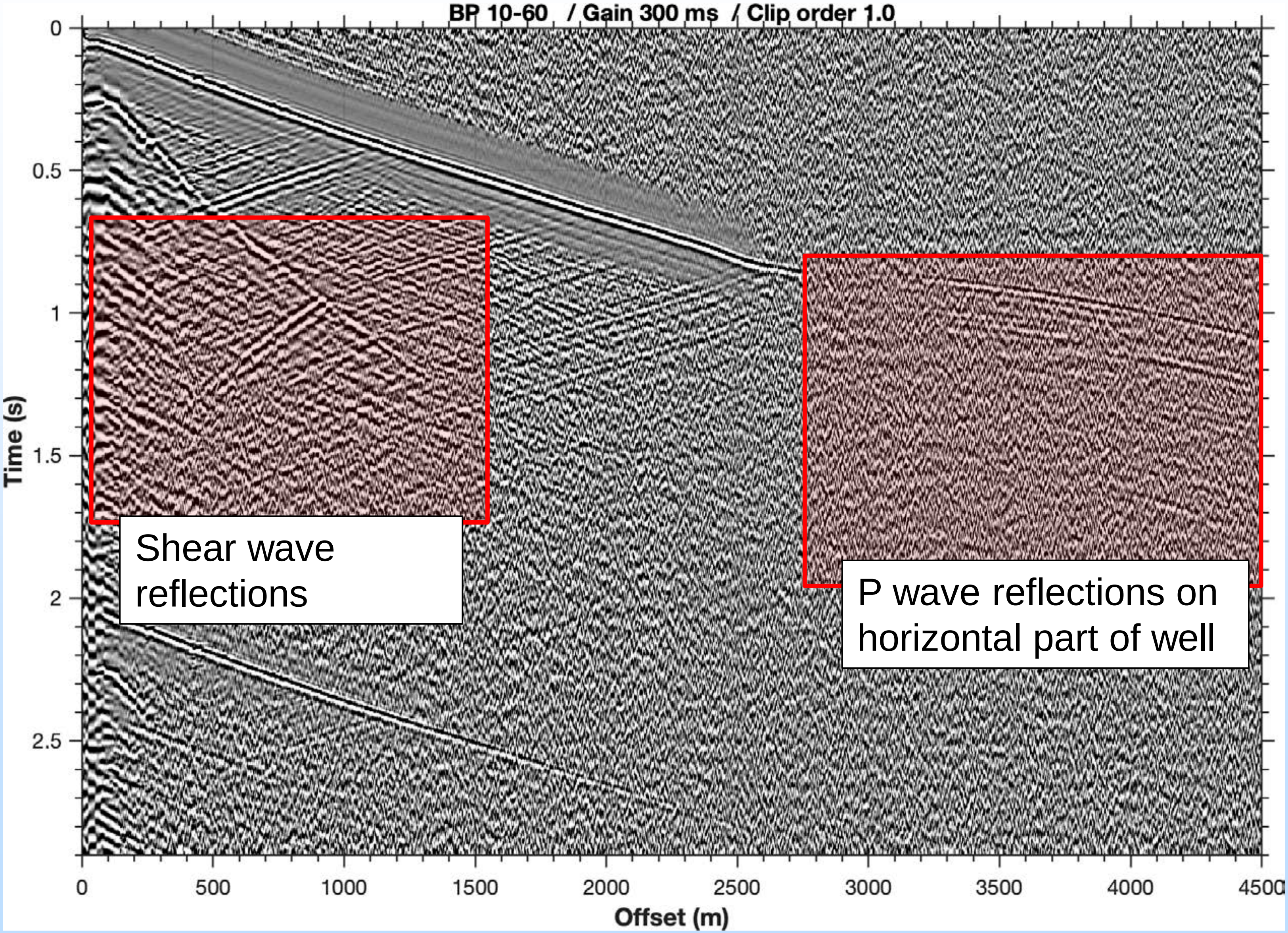
- Allow for swept azimuthal orientation of $S_H$
- Detect anisotropy using shear wave splitting



# Eagle Ford Shale Laboratory – First field trial with new SOV




# EFSL – SOV/DAS


BP 10-60 / Gain 300 ms / Clip order 1.0
Time (s)
0
0.5
1
1.5
2
2.5
Offset (m)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Shear wave reflections
P wave reflections on horizontal part of well

# Accomplishments to Date

- Testing of optimal parameters for SOV/DAS acquisition
- Developing automated seismic processing flow for quasi-real time DAS/SOV processing
- Supported first SOV with slewing bearing for directional $S_h$

# Lessons Learned

– Geophone for recording SOV pilot trace when installed directly below the SOV provides better recording of the wavelet
– Installing pre-made concrete yields poor coupling as the ground needs to be enough compacted
– Engineered fibers can be used with the small motors to record higher frequencies
– Engineered fiber can enable the acquisition of surface seismic with DAS

# Synergy Opportunities

- SOVs were used in the Eagle Ford Shale Laboratory project (Texas A&M, LBNL and Chesapeake Energy)
- The ADM CCS project has been investing in SOV/DAS based monitoring
- Enhanced geothermal system (EGS) projects, such as at FORGE, could benefit from the oriented $S_H$ SOV to identify anisotropy and evaluate fracture stimulation
- University of North Dakota EERC (Energy and Environmental Research Center) SOVs at Bell Creek Field, Montana

# Project Summary

- Time-lapse VSP acquired with SOV can be used to conduct continuous reservoir monitoring (with automated acquisition and data processing);
- Acquiring VSP surveys using DAS and SOV sources offers an alternative to surface vibroseis surveys for TL monitoring;
- DAS/SOV provide datasets sufficient to image injection depth;

# Appendix

– These slides will not be discussed during the presentation, but are mandatory.

# Benefit to the Program

- Goal (1) Develop and validate technologies to ensure 99 percent storage permanence by reducing leakage risk through early detection mitigation.
- Goal (2) Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness by advancing monitoring systems to control and optimize CO2 injection operations.
- Successful development of SOV-DAS will enable more cost effective monitoring and can serve to either reduce or replace more expensive traditional 4D seismic methods.

# Project Overview

## Goals and Objectives

- Project Goal: To improve the performance of SOV-DAS by trialing new field hardware and data processing methodologies. Develop best practice and guidance for incorporating SOV-DAS into permanent reservoir monitoring programs.
- This project will be considered a success if it is able to improve SOV-DAS performance such that it provides equal or better quality data as compared to current state-of-the-art approaches to seismic acquisition.

# Organization Chart

- Julia Correa, LBNL PI
- Julia Correa, LBNL, Data processing and analysis
- Todd Wood, LBNL, Electrical engineering and software development
- Paul Cook, LBNL, Mechanical engineering
- Michelle Robertson, Project Scientists – field logistics and operations management

- Collaborators:
  – Australian CO2CRC and Curtin University (Roman Pevzner lead scientist for Otway Stage 3 experiment)
  – Paul Barraclough CO2CRC Project Leader for Stage 3

# Gantt Chart for LBNL Target Research Program

| Milestone Reporting accompanies Quarterly report | Q1 FY19 | | | Q2 FY19 | | | Q3 FY19 | | | Q4 FY19 | | | FY20 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subtask Description** | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | Q1 | Q2 | Q3 | Q4 |
| Task 1 Project Management and Planning | | | | | | | | | | | | | | | | |
| Task 2 SOV-DAS | | | | | | | | | A* | | | B | C | D | | |
| Task 3 Monitoring Leakage: Joint EM and Seismic | | | | | | | | | | | | A | | B/C | D | |
| Task 4 Monitoring Technology for Deep $CO_2$ Injection | | | | | | | | | A | | | B | | | C | D |
| Task 5 US-Japan CCS Collaboration on Fiber-Optic Technology | | | | | | | | | A/B | | | C/D | E | F/G | H | |

| Task | Milestone Description* | Fiscal Year 2019 | | | | FY20 | Planned Start | Planned Completion Date (Reporting | Actual Start | Actual End | Comment (notes, explanation of deviation from plan) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | | Date | Date)** | Date | Date | |
| **Milestone 2-1 (A)** | SOV/DAS automated data processing algorithms and workflows | | | x | | | 10/1/2018 | 6/30/2019 (1/31/2020) | | | AOP Tracked |
| **Milestone 2-2 (B)** | Data report on SOV/DAS baseline surveys and initial testing of 2nd Gen SOV | | | | x | | 10/1/2018 | 9/30/2019 (10/31/2019) | | | |
| **Milestone 2-3 (C)** | Data acquisition and analysis covering monitoring period | | | | | Q1 | 10/1/2018 | 12/31/2019 (1/31/2020) | | | |
| **Milestone 2-4 (D)** | $CO_2$ plume detection - difference of DAS/SOV surveys | | | | | Q2 | 10/1/2018 | 3/31/2020 (4/30/2020) | | | |
| * No fewer than two (2) milestones shall be identified per calendar year per task (per previously separate project) | | | | | | | | | | | **Note: Milestone reporting accompanies quarterly report, one month after end of quarter. |

# Bibliography


- Yavuz, S., Freifeld, B., Pevzner, R., Dzunic, A., Ziramov, S, Bóna, A., Correa, J., Tertyshnikov, K., Urosevic, M., Robertson, M., Daley, T., (2019) The initial appraisal of buried DAS system in CO2CRC Otway Project: the comparison of buried standard fibre-optic and helically wound cables using 2D imaging, Exploration Geophysics (50) 1, https://doi.org/10.1080/08123985.2018.1561147
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- Correa, J., Tertyshnikov, K., Wood, T., Yavuz, S., Freifeld, B., Pevzner, R., (2018) Time-Lapse Vsp with Permanent Seismic Sources and Distributed Acoustic Sensors: Co2crc Stage 3 Equipment Trials, 14th Greenhouse Gas Control Technologies Conference Melbourne (GHGT-14)