23rd April 2018

13th CO2GEONET OPEN FORUM
High-resolution offset VSP using fiber optic acoustic sensor – CO2CRC Otway Site, Australia

A. Chalari, Silixa Ltd

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Agenda

- Introduction
- Technology
- Application Sectors
- Carina system
- Otway Project
- VSP Results

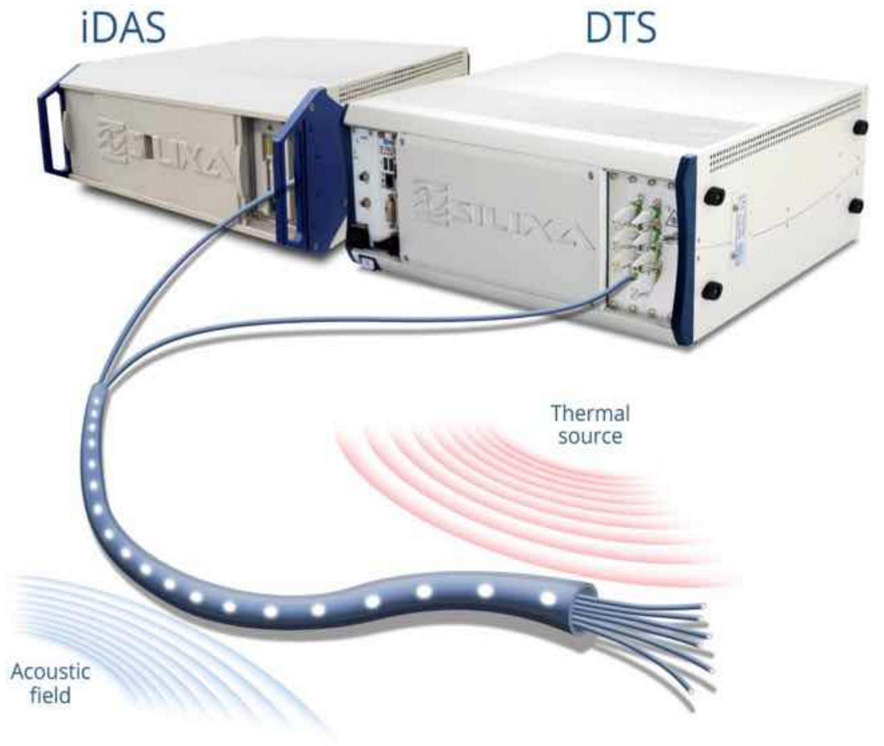
Silixa's technology – key differentiators

iDAS – intelligent Distributed Acoustic Sensor

- Amplitude, Frequency and Phase of the acoustic vector
- Wide dynamic range ensures recognition of diverse range of events
- Measurements possible on both SM and MM fibre optic cables enabling the use of legacy fibres

DTS – Distributed Temperature Sensor

- Thermal profiling with high precision over long ranges
- Spatial resolution
- Both SM and MM systems are available
- Temperature resolution over long measurements



- Continuous SNR Improvement through optimisation of optoelectronics and **light management**

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Silixa – served sectors today

Oil & Gas

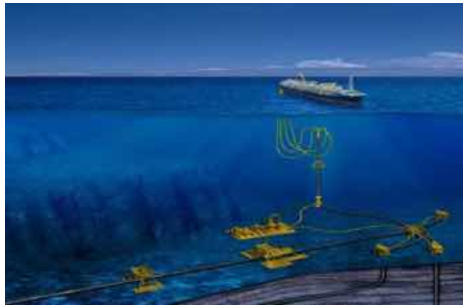
Conventional

- Seismic
- Production Monitoring
- Well integrity

Un-conventional

- Fracture Monitoring
- Microseismic
- Flowback Monitoring

SURF



Pipe & Cable Integrity

- Event Detection
- Leak Detection
- Power Cable Monitoring

Flow Assurance

- Thermal Profiling
- Slug Detection
- Flow trending

Environmental

Geotechnical

- Seismicity
- Geothermal Monitoring
- Dam Monitoring

CO2 Sequestration

- **Seismic**
- **Time Lapse monitoring**
- **Cavern Integrity**

Mining

Process Metering

- Process flow Metering

Geophysical

- Seismic
- VSP
- Microseismic

Products

- XT-DTS
- ULTIMA™DTS
- iDAS™
- Cable & Accessories

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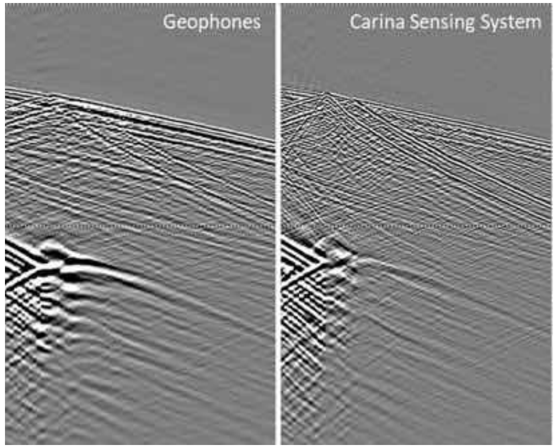
Environmental applications

CO_2 Monitoring

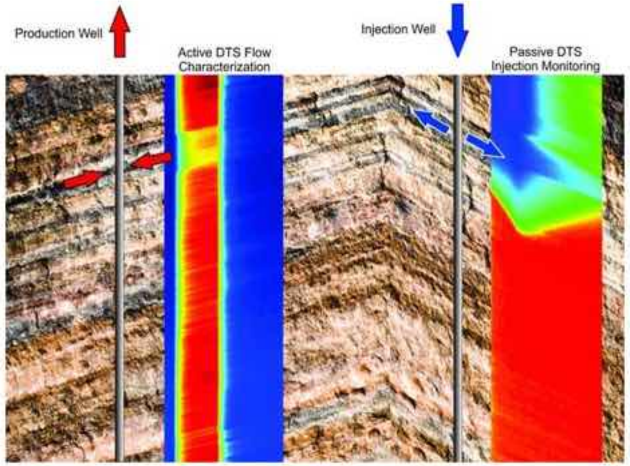
- Time-lapse borehole seismic
- Surface seismic
- Passive monitoring for potential micro-seismic events ensures caprock integrity
- Continuous temperature monitoring – Early detection of leaks or gas migration
- Acoustic detection for gas migration and leaks



*Data and images courtesy of CO2CRC - CRC-3.

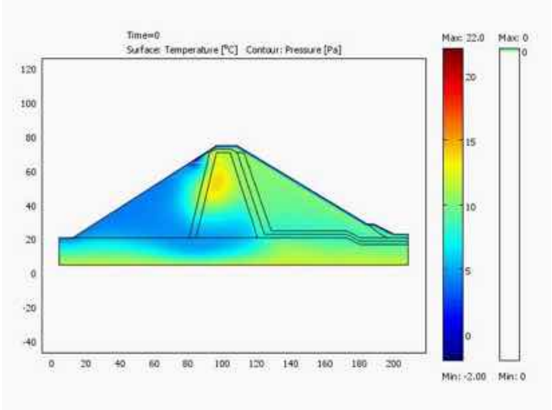
Geothermal

- Temperature Characterization
- Fracture Interconnectivity
- Integrity Monitoring
- Well Field Optimization
- Active Characterization



Seepage detection in dams and dykes

- Real-time processing of temperature data
- Visual presentation of temperature and seepage flow via web interface
- Detection of sudden temperature changes
- Surveillance of monitoring performance and quality check of cable
- Automatic export of selected evaluated data



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Carina System

- DAS SNR is largely governed by how much light can be usefully collected from the optical fibre
- We want low loss fibre – to achieve *long range*, but high scattered fibre – to get *more signal*
- This apparent contradiction is overcome by engineered fibre without introducing significant excess loss in the forward propagating light (Constellation fibre)
- The new iDASv3 interrogator provides enhanced measurement with standard fibre, but gives a step change improvement (more than x100) with new engineered fibre
- The SNR improvements are transformative for DAS applications

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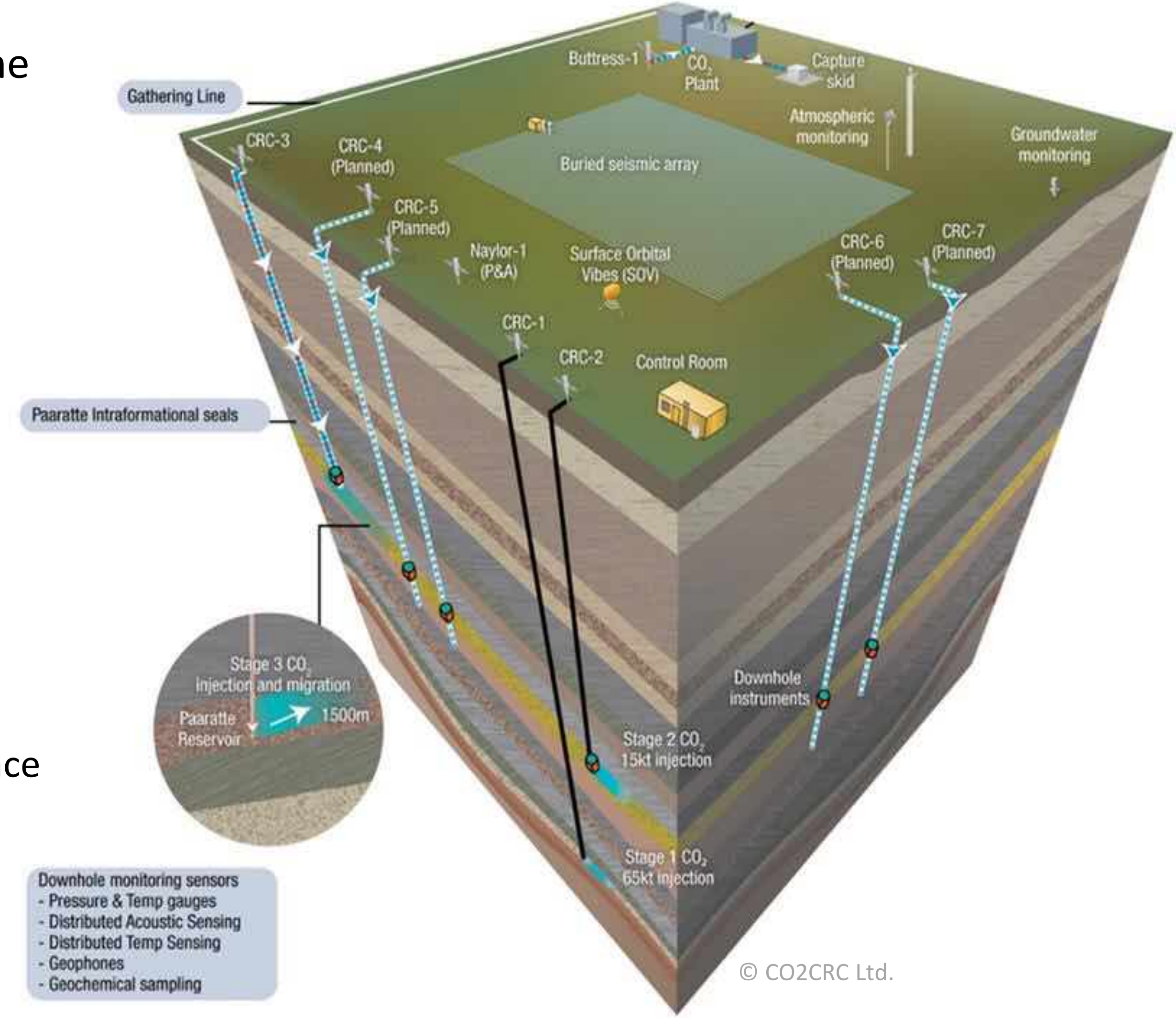
CO2CRC - Otway Australia

Otway Project, in south-western Victoria, Australia, is the first geological CO_2 storage demonstration project in Australia and is one of the largest CO_2 storage laboratories in the world

Stage 1 2004-2009
- Demonstrate safe transport, injection and storage

Stage 2 2009-2019
- Demonstrate safe injection and monitoring

Stage 3 2016-2022
- Demonstrate safe, reliable and cost-effective subsurface monitoring of CO2



Seismic Monitoring Objectives in Stage 3
- Develop deployment and operational processes for new technologies
- Provide risk targeted subsurface monitoring options to potentially replace more costly and invasive surface based monitoring techniques.
- Improve operator response times to anomalies in plume development
- Provide visualised 4D evolution of plume through in-well seismic monitoring
- 2017- (5 wells)- Subsurface monitoring system

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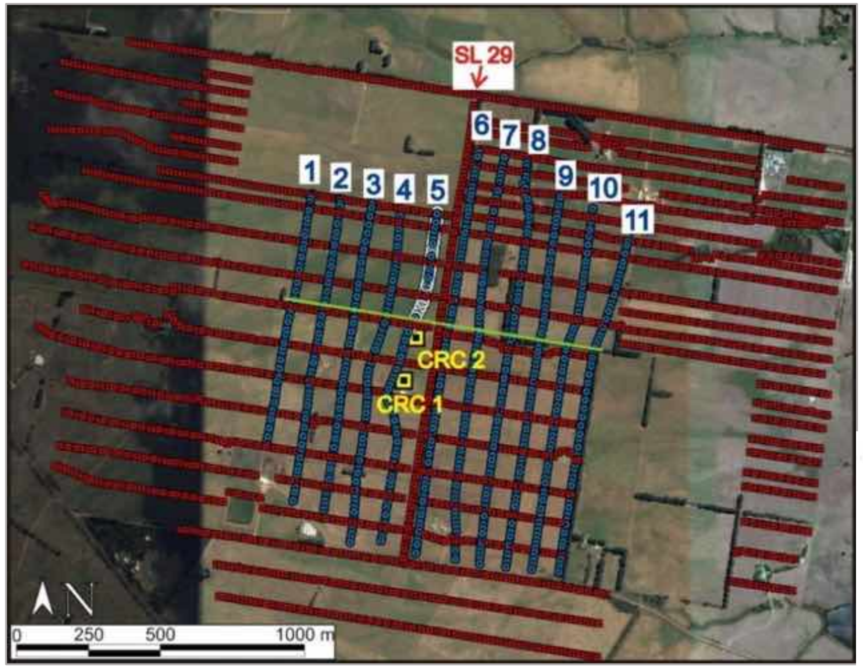
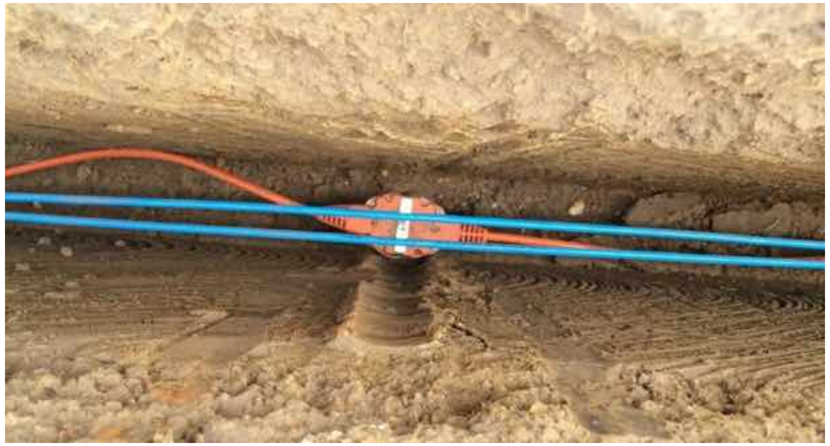
CO2CRC - Otway Australia – Seismic Technology Proving Ground

Geophones and Fibre-optic deployment

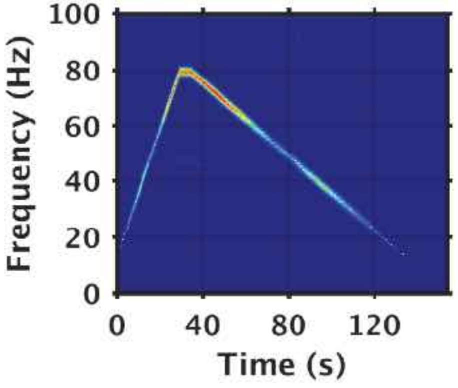
~35 km fiber-optic cable

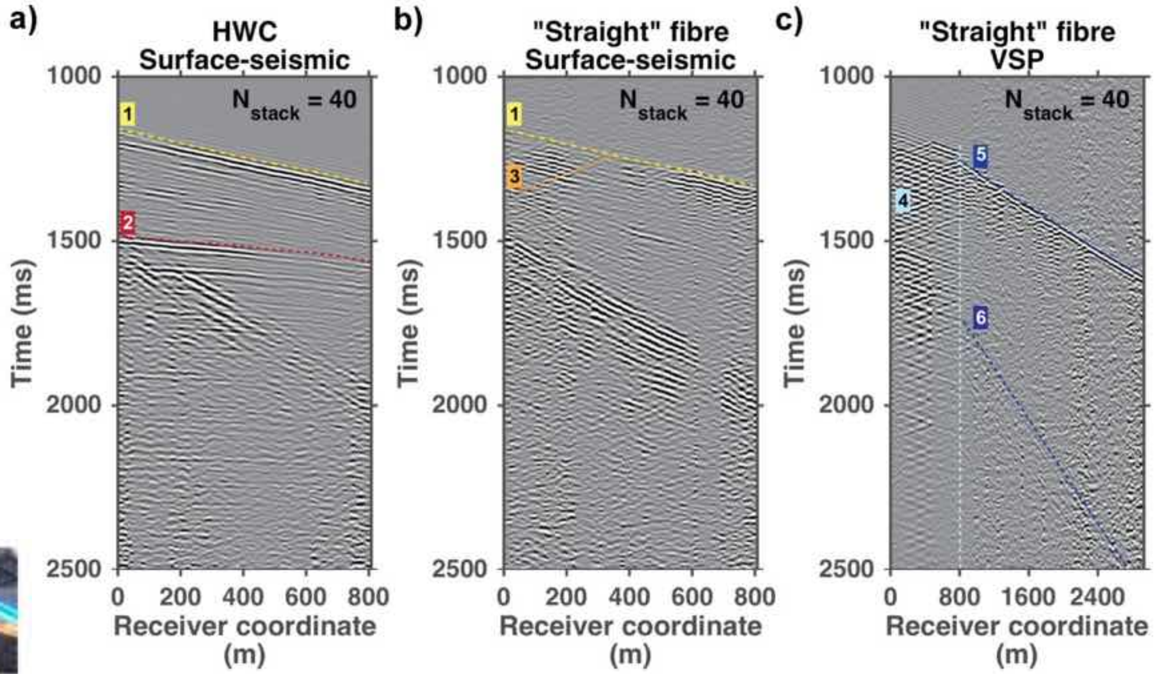




Helical Wound Cable

Permanent Surface Orbital Vibrators

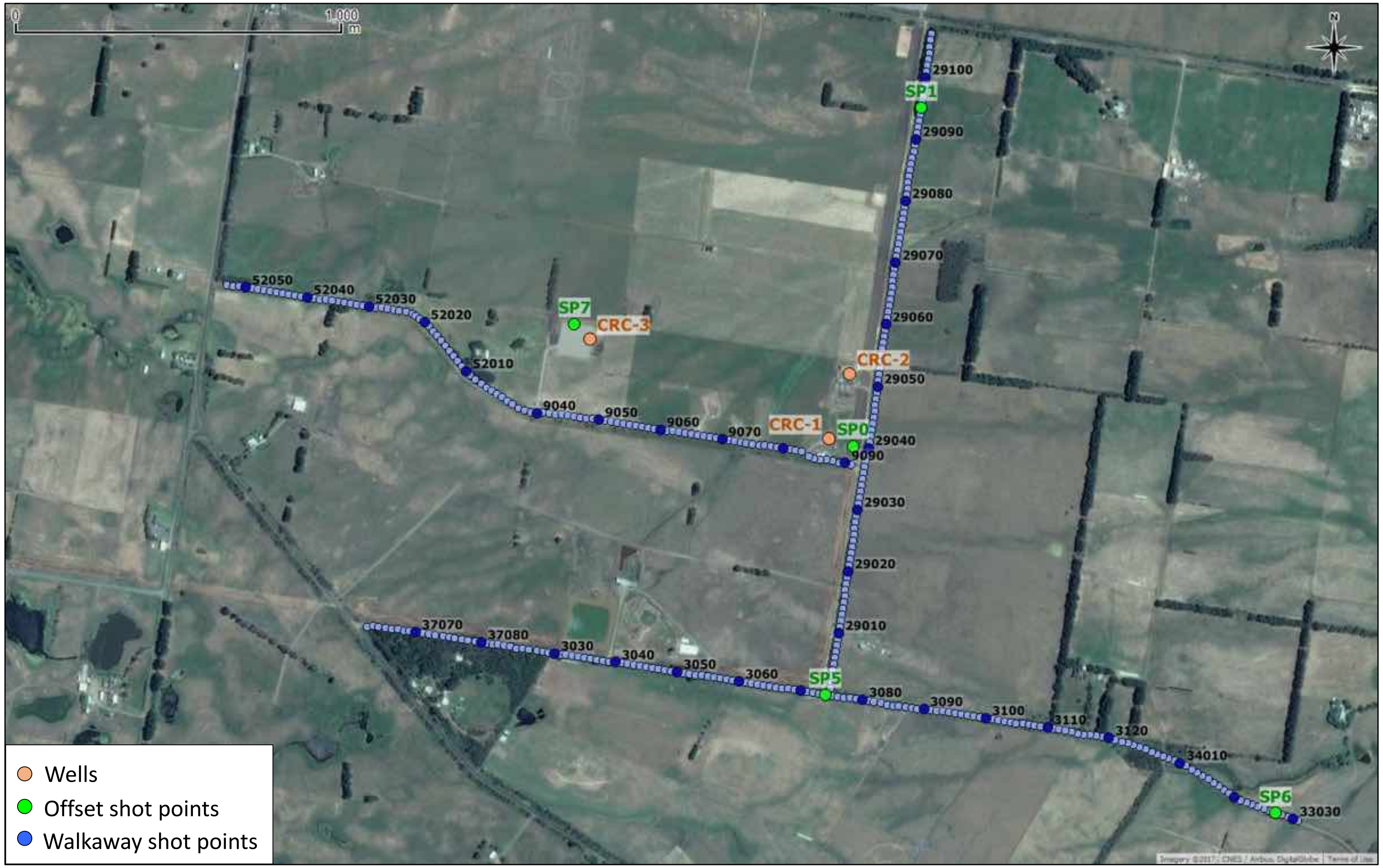




Freifeld et al, EAGE 2016

Stage 3 - multi-well VSP using conventional and permanent vibroseis sources

- CRC-3 drilled to 1667m depth
- Cemented fibre-optic cable behind casing:
  - Standard single-mode fibre (iDAS v2)
  - Enhanced backscatter fibre - Constellation (iDAS v3)
- Test DAS in relation to different offsets and directions



Correa et al. 2017 The Leading Edge 36(12)

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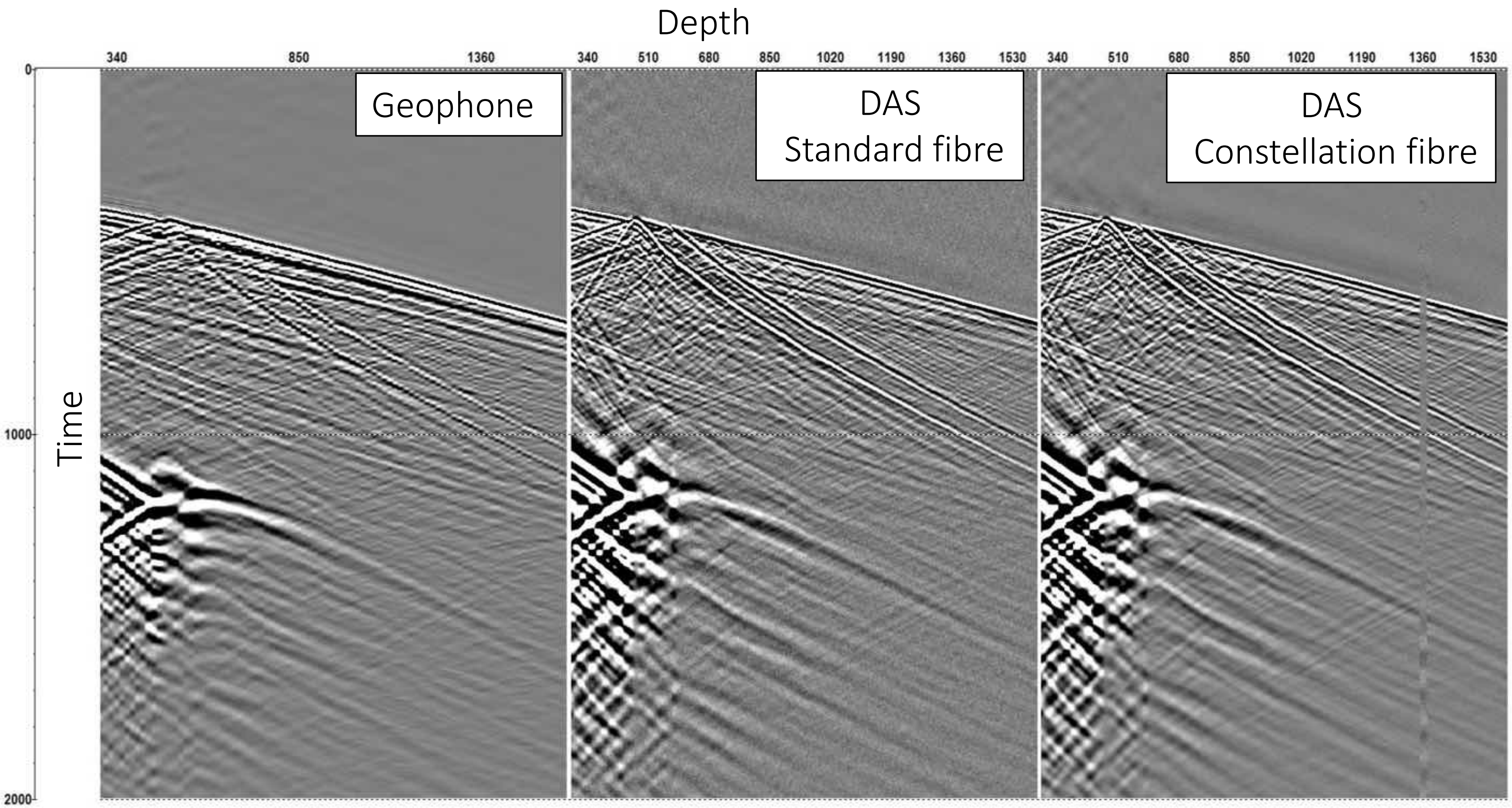
CO2CRC -CRC-3 VSP using cemented in fibre (700 m offset)

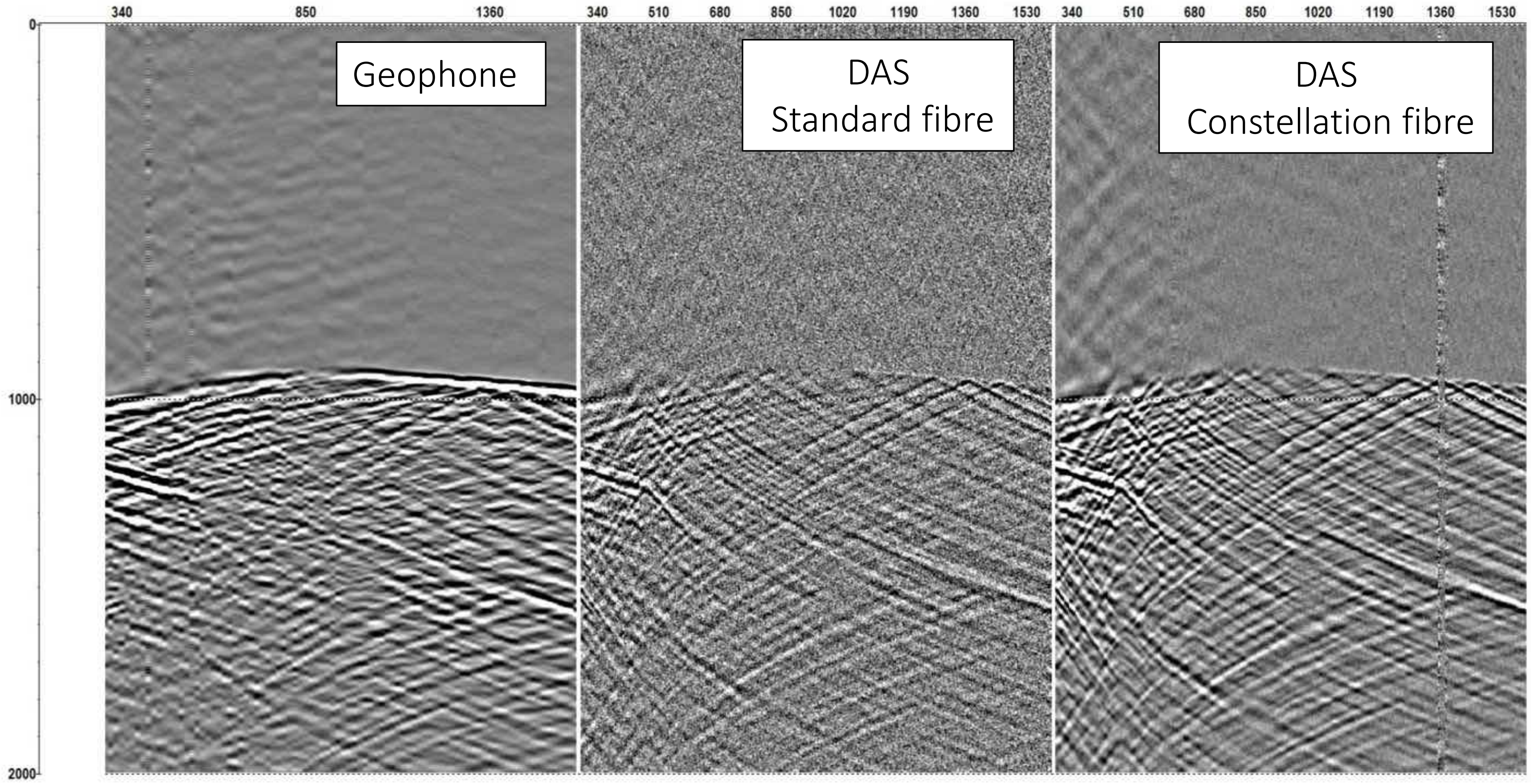
- DAS data converted to particle velocity for comparison to Geophones
- Geophones acquired at 15 m interval
- DAS channel spacing at 1 m
- PP-wave reflections seen on both DAS and Geophones
- PS-waves noted on DAS not present in geophone data



Correa et al. 2017 The Leading Edge 36(12)

CO2CRC -CRC-3 VSP using cemented in fibre (1800 m offset)

- Because of the linear cable directionality, the S/N of the direct-wave arrival for iDAS was not calculated for far-offset position
- Upgoing and downgoing waves, as well as PS-waves are well imaged in DAS and better recorded than geophones, despite the high level noise of the DAS v2



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Conclusions

- Accurate comparison between DAS and Geophone require conversion into equivalent units. After conversion DAS and geophones very similar
- For near offsets iDASv2 and iDASv3 show similar S/N, with geophones exhibiting ~12 dB higher sensitivity
- DAS data might provide more detailed velocity information compared to geophones.
- SNR for single-mode fiber decreases at far offsets, where for the Constellation fiber it remains high.
- At far offsets (1800 m) reflected waves are better captured in DAS than geophones due to higher spatial sampling

*Data and images courtesy of CO2CRC Ltd

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Acknowledgments

- The Authors would like to acknowledge CO2CRC Ltd and its members, for funding, operational planning and execution support, and utilising the Otway National Research Facility. This includes funding provided by ANLEC R&D who is supported by Australian Coal Association Low emissions Technology Limited and the Australian Government through the Clean Energy Initiative. National Geosequestration Laboratory (NGL) is also acknowledged for providing the seismic sources (INOVA Vibrators) for this project.
- LBNL funding was provided through the Carbon Storage Program, U.S. DOE, Assistant Secretary for Fossil Energy, Office of Clean Coal and Carbon Management through the NETL.

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