DAS Field Trials for Near-Surface Geotechnical Properties, Earthquake Seismology, and Mine Monitoring

WISCONSIN 	Herb Wang, Dante Fratta, Xiangfang Zeng, Neal Lord, Chelsea Lancelle, Alex Baldwin, Ethan Castongia
SILIXA	Michael Mondanos, Athena Chalari, Thomas Coleman

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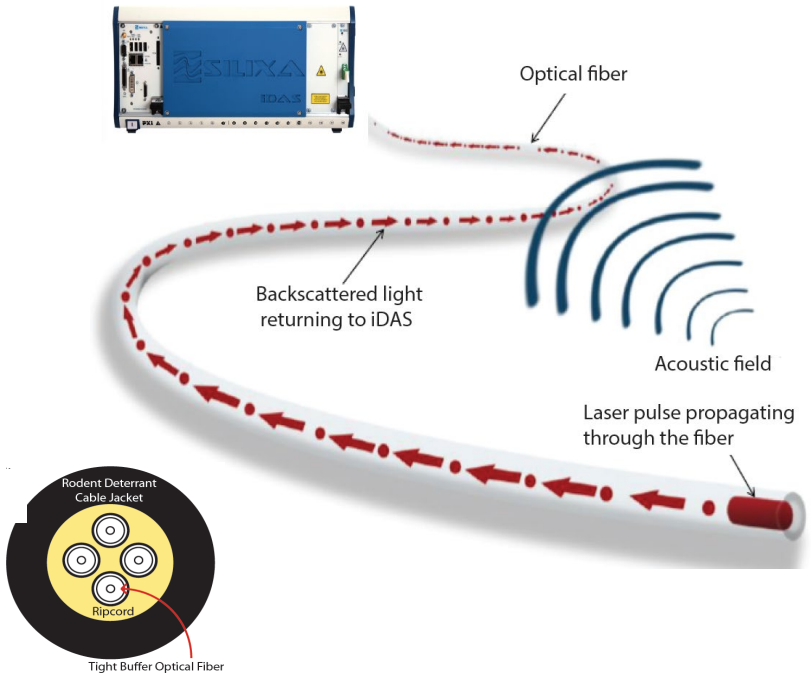
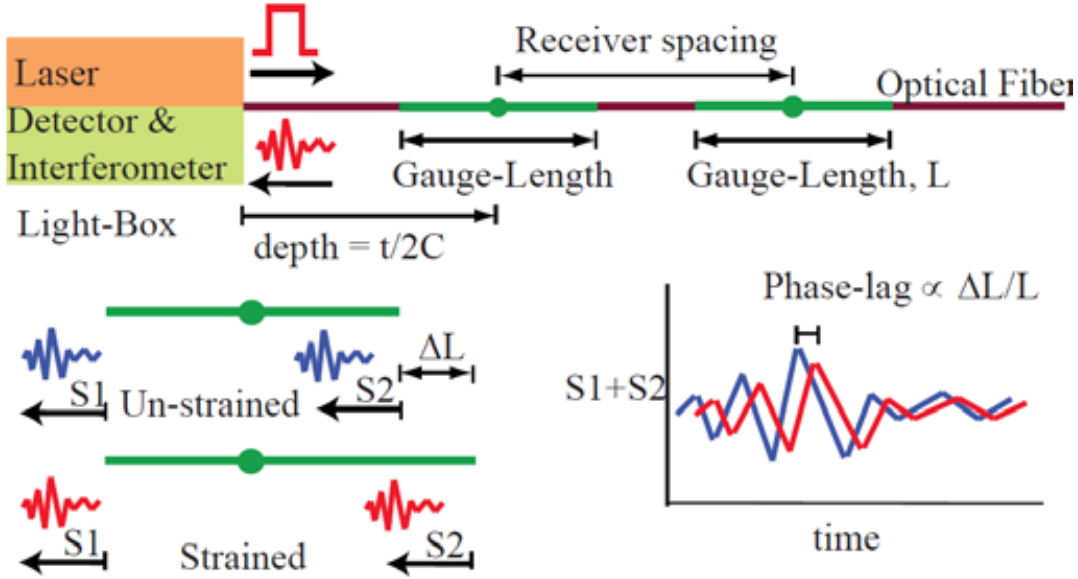
OUTLINE

- DAS principles
- Lake Mendota (March 2012) 90-m x 4 cables in lake ice
- Garner Valley (Sept. 2013) 762-m x 2 cables in alluvium
- Brady Hot Springs, NV (March 2016)
  - 1500 m x 400 m x 400 m (one borehole) natural laboratory
  - 9-km cable layout for monitoring physical properties and MEQs
- Lafarge-Conco room-and-pillar mine (July 2017) 270-m x 3 cables in 7-cm deep trench cut by pavement saw

Silixa iDAS™ Interrogator

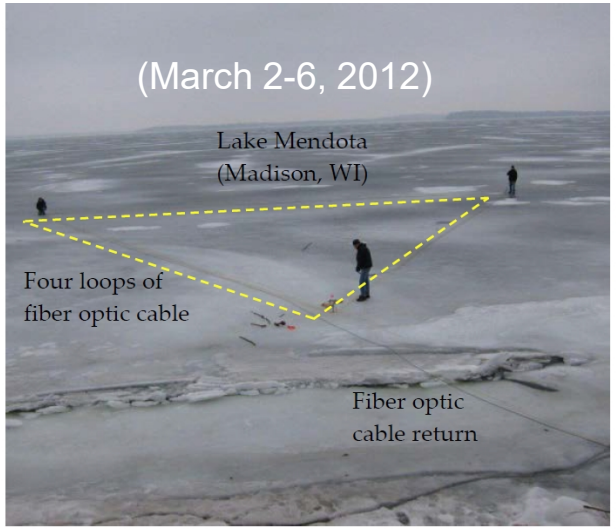


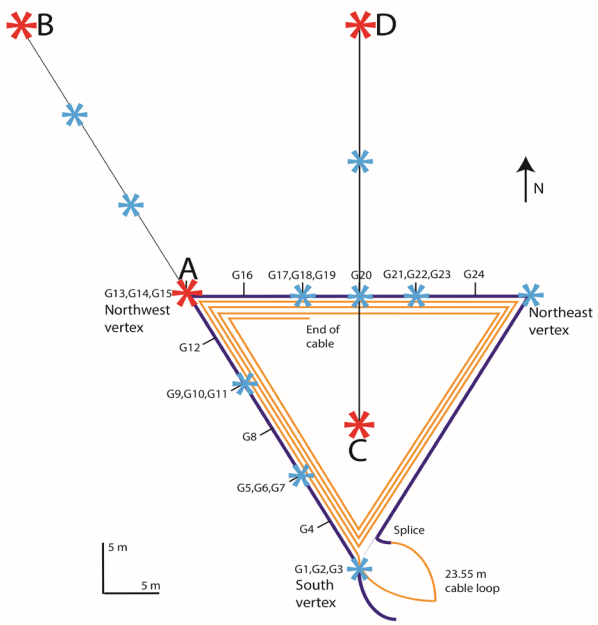


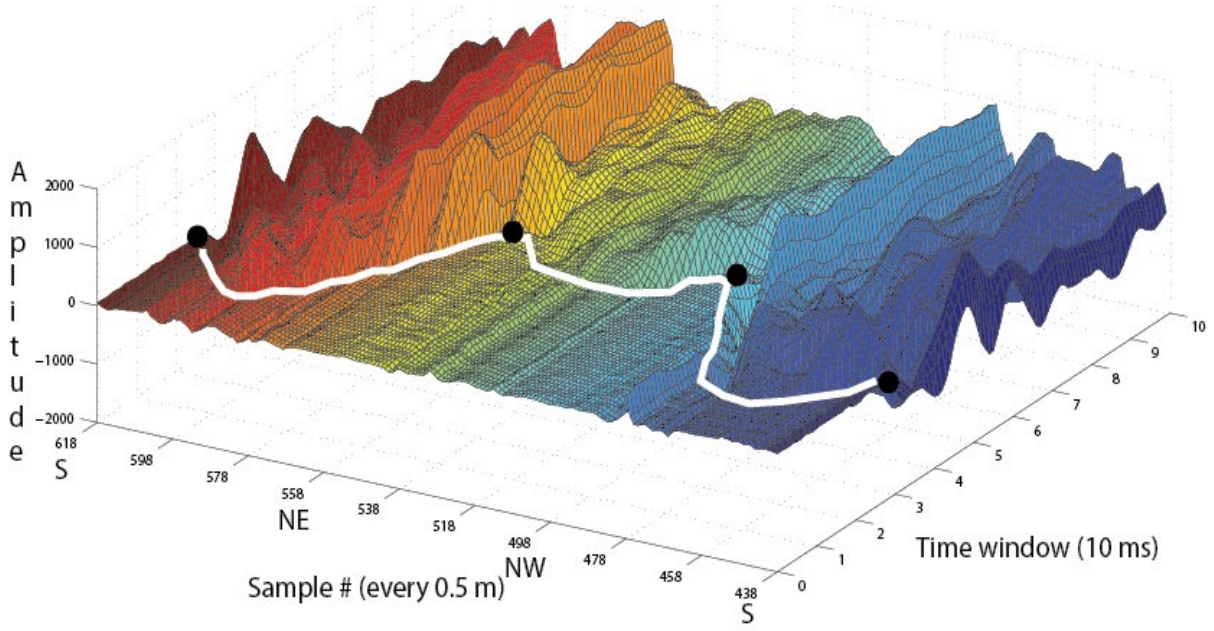
(Bakku, MIT Ph.D. thesis, 2015, p. 114)

DAS sends out light pulses every millisecond. The phase difference of backscattered light in every 10-m gauge length measures strain rate. Sensitivity to ground motion is in cable direction. (Parker, First Break, 2014)

Ice-covered L. Mendota: 90-m DAS Array

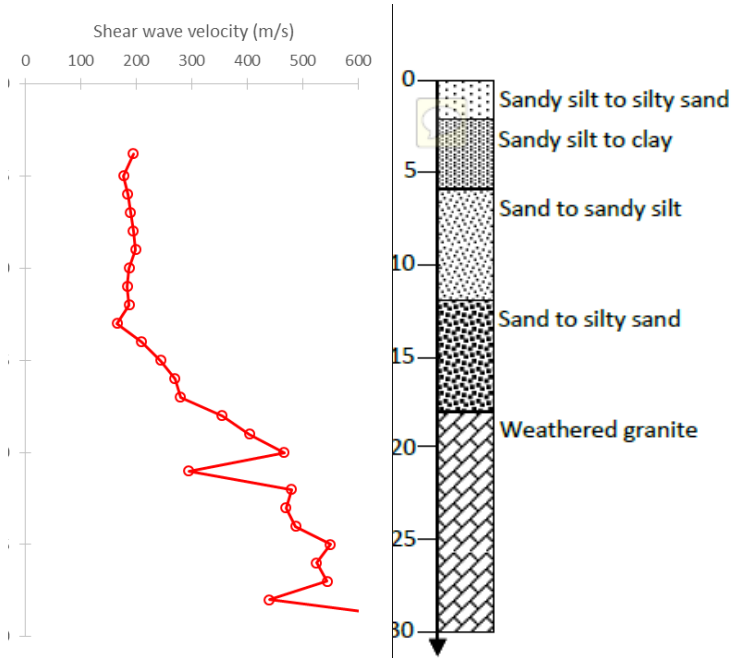


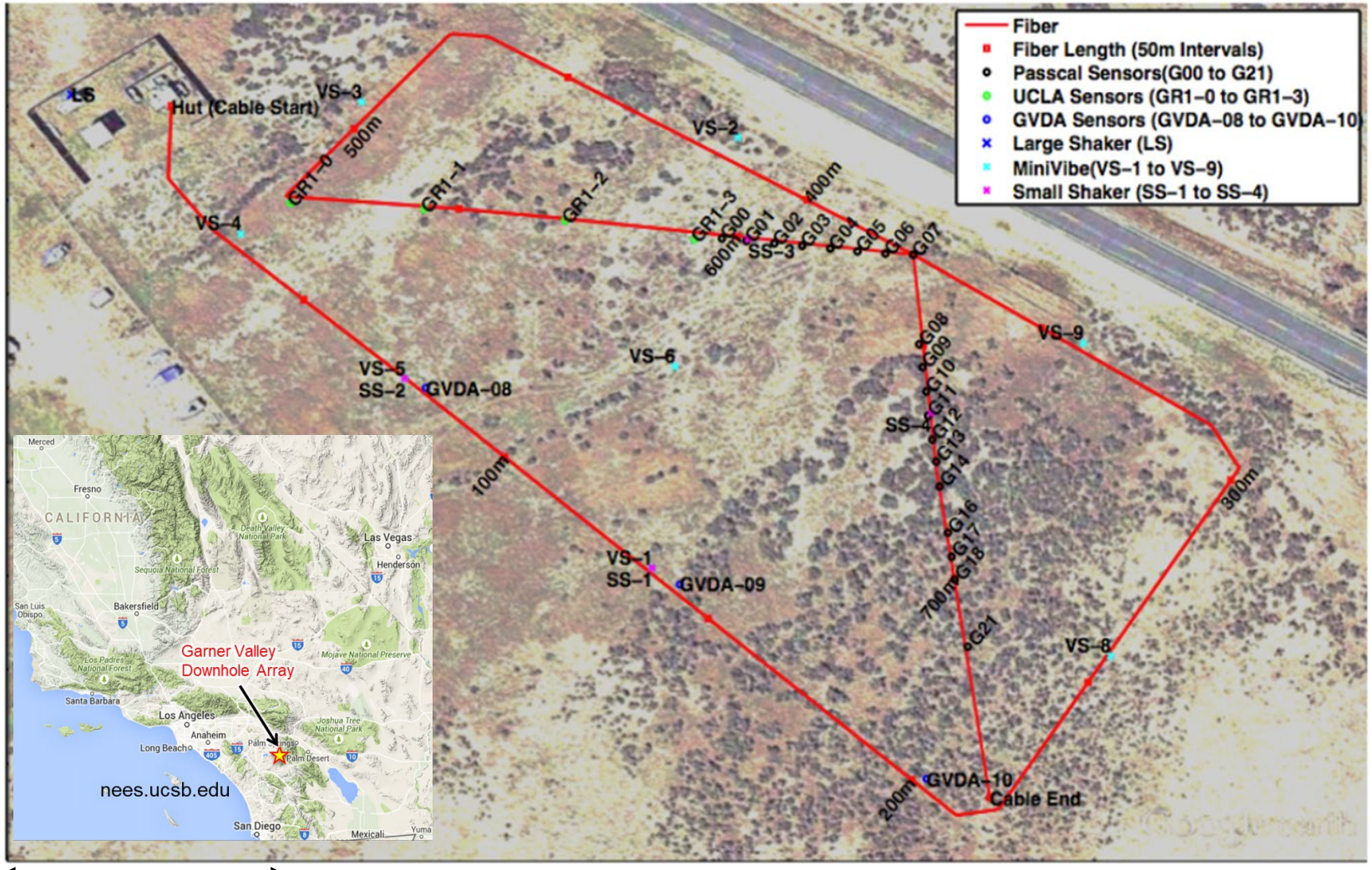




E. Castongia, et al. (2017), J. Eng. & Env. Geoscience, v. 22(2), pp. 167-176.

Garner Valley: 762-m DAS Array

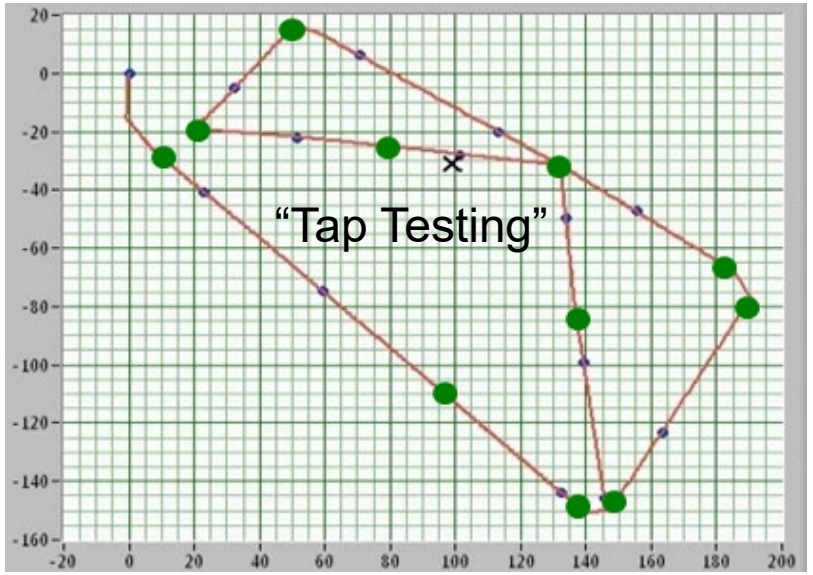




50 m

Lancelle, et al., (2020). AGU special issue on Distributed Acoustic Sensing

Cable, Geophones, and Mini-Me Source



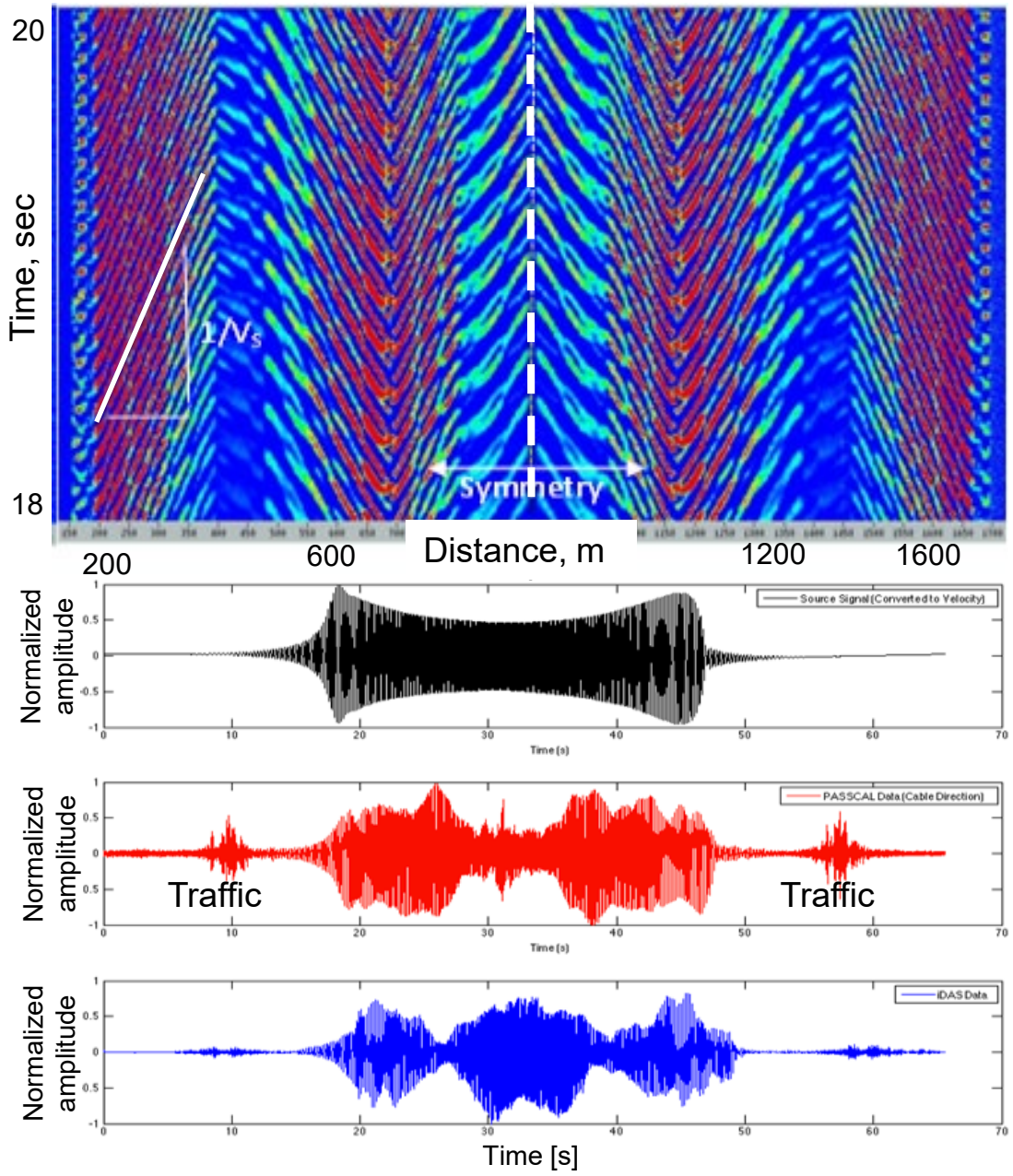
Traces from All Channels

- Traces are symmetric about end of cable where it loops back.
- Increasing and decreasing time of arrivals is due to varying distances of cable from source. Average velocity is 200 m/s.

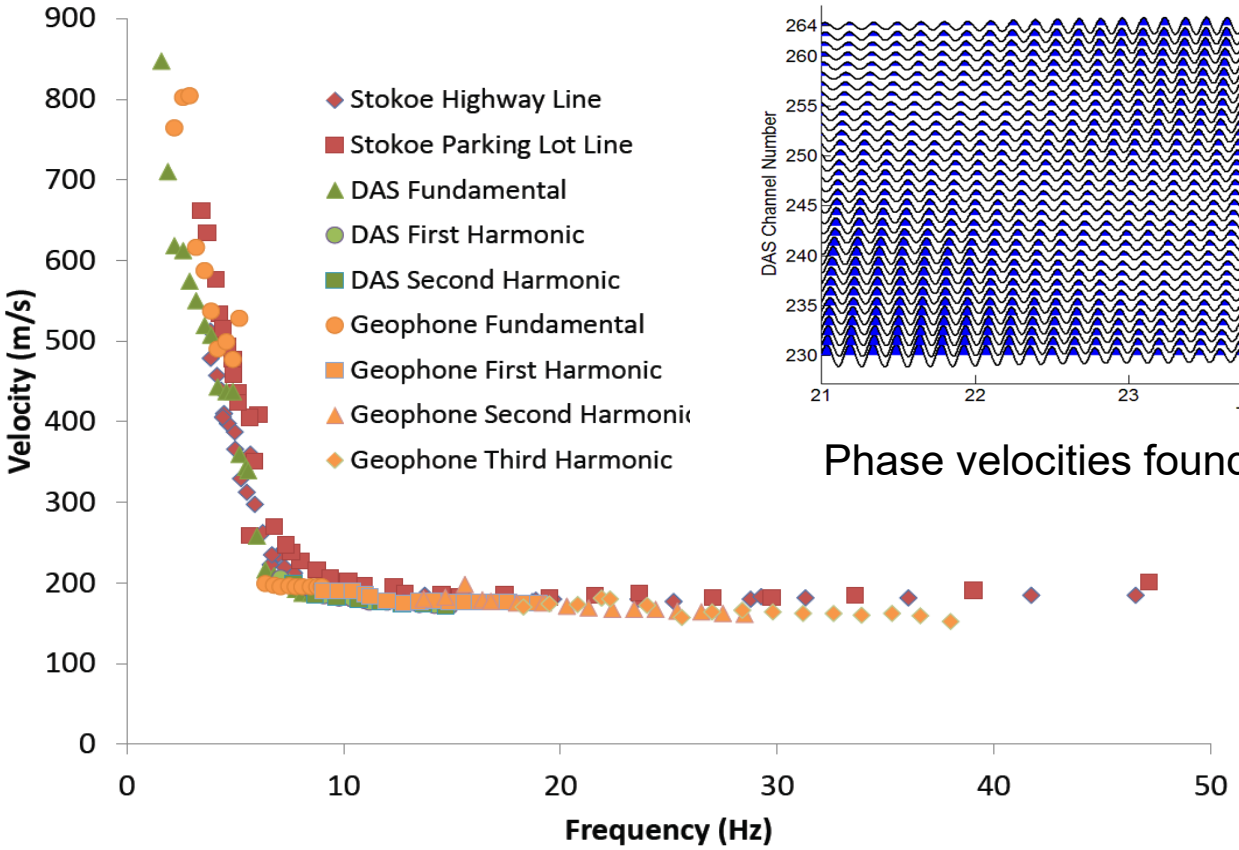
45-kN source: up from 0.4 – 10 Hz in 30 sec and down for 30 sec.

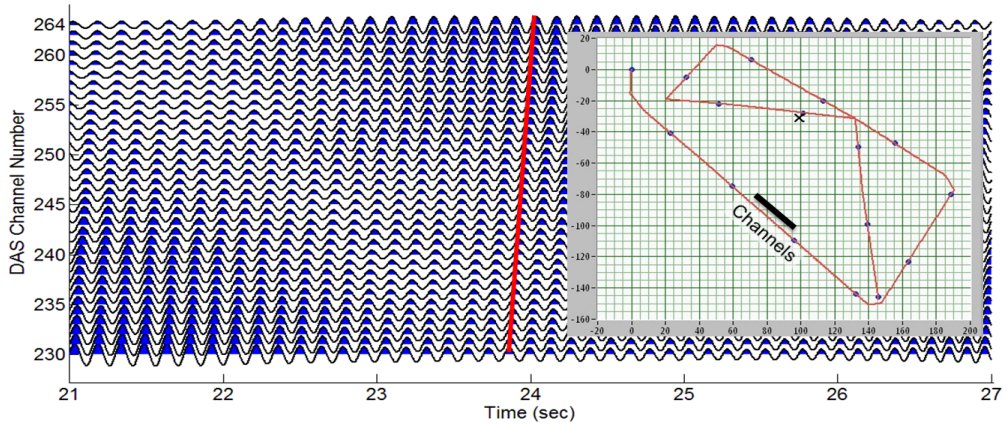
4.5-Hz vertical geophone trace

DAS strain rate response of a single channel adjacent to geophone



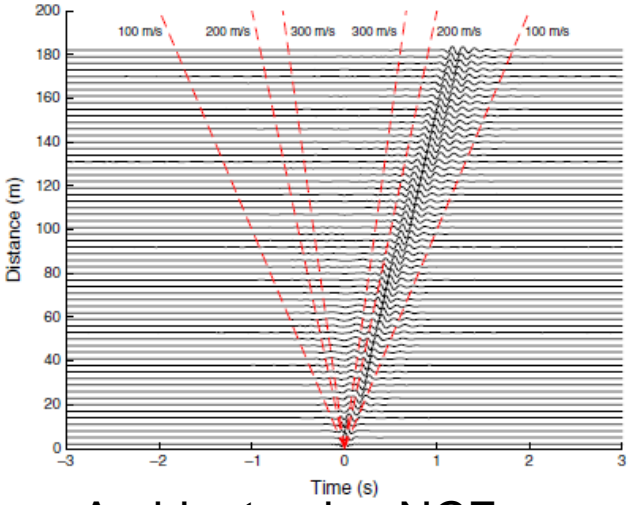
Multichannel Analysis of Surface Waves (MASW)





Phase velocities found in 2-Hz bands

Surface-wave Dispersion using Swept-Frequency Source.

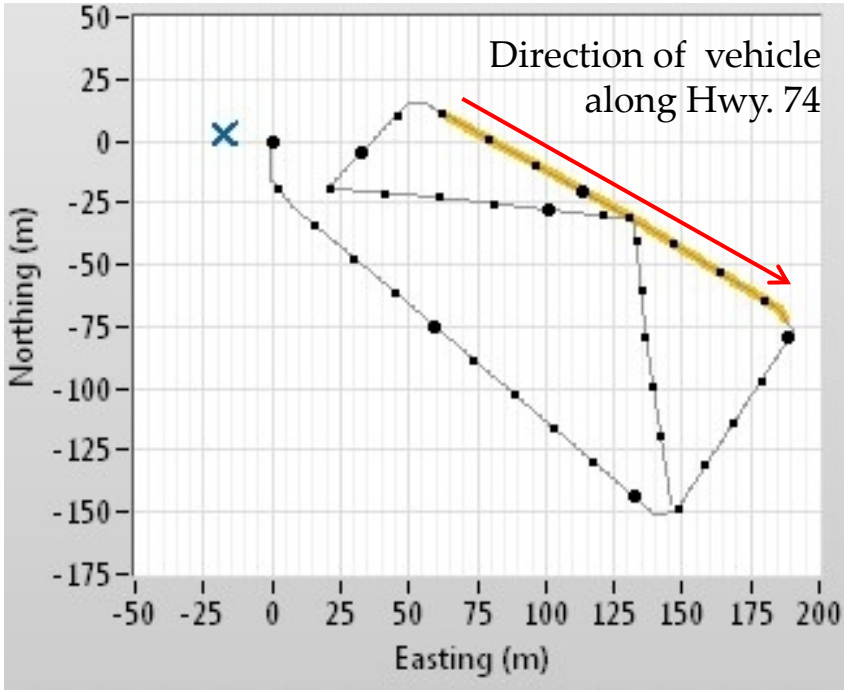


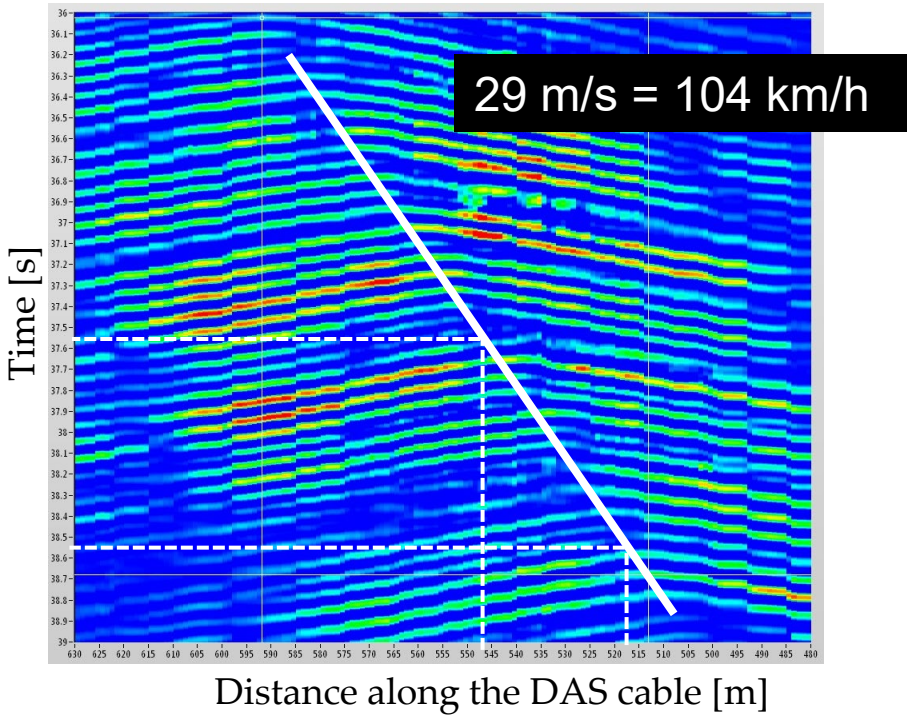
Ambient noise NCFs along long line.

1. Symmetric components of NCFs for longline were slant stacked in frequency domain.
2. Dispersion curve was identified as maxima in the frequency–velocity diagram.
3. Dispersion was comparable to Mini-Me source between 5 and 10 Hz.

Zeng et al. (2017) BSSA, v. 107,pp. 603–610.

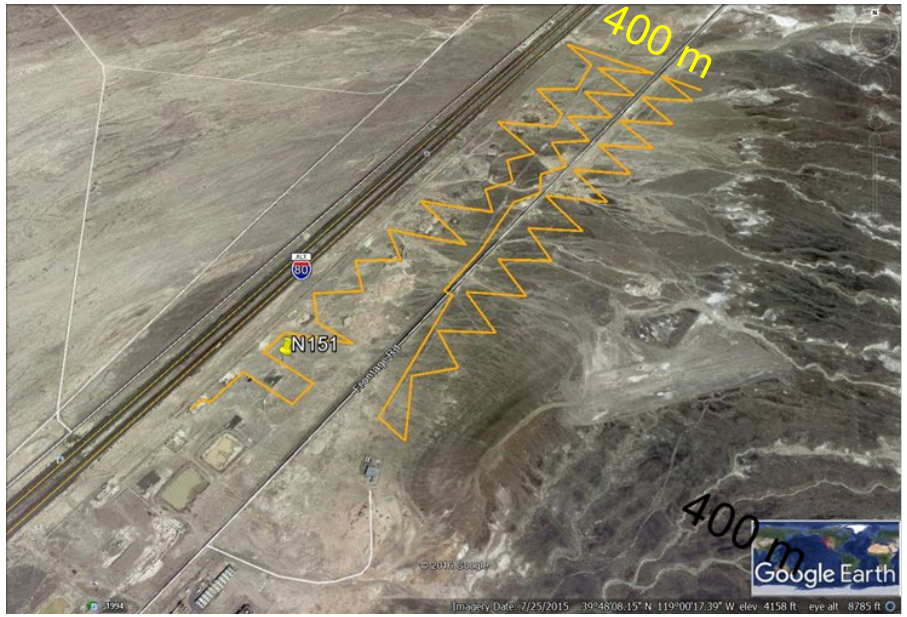
Traffic Monitoring





Brady Hot Springs, NV (March 2016) 9-km DAS Array

- DAS array includes cable hanging in a 300-m deep borehole near in SW corner.
- Zig-zag pattern is to deal with DAS directional sensitivity.

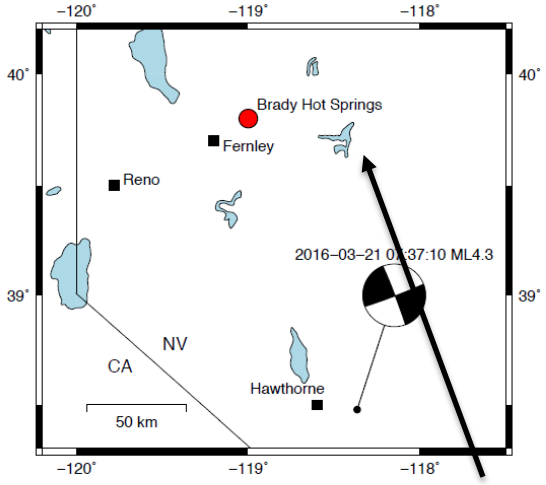


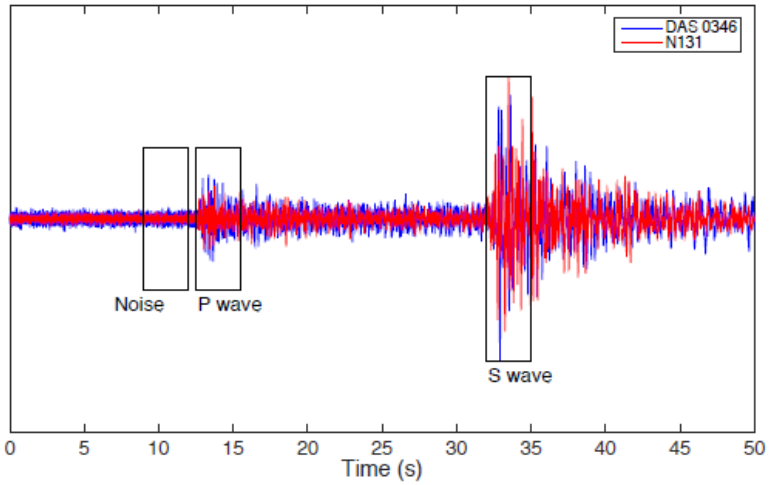
Vibroseis source locations on about 50-m grid operated repeatedly over 21 days. 44 TB data.

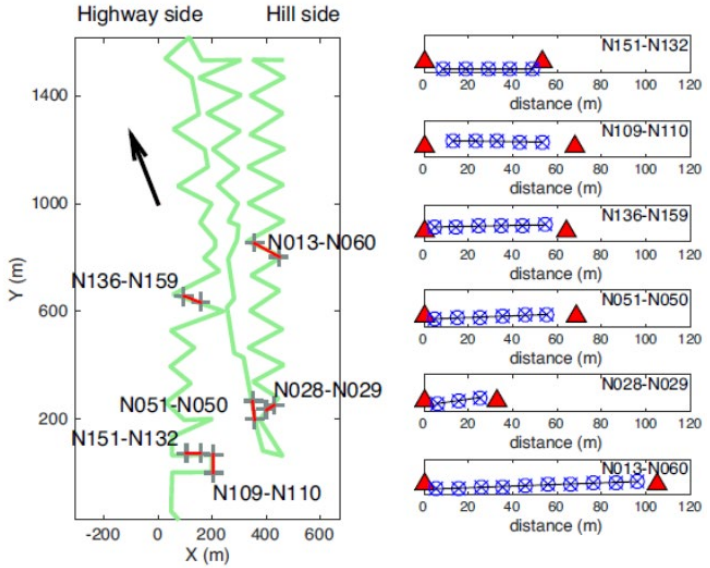
238-nodal array spaced on approximately 50-m grid

Feigl (2018), 43rd Stanford Geothermal Workshop.

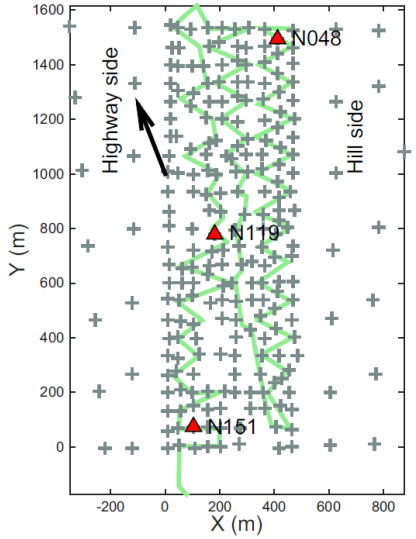
DAS and Geophone Arrivals from M_L 4.3 Earthquake 150-km SSW







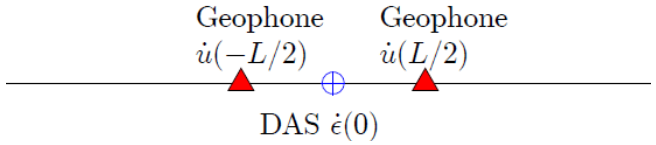
Geophones spanning DAS channels several gage lengths apart



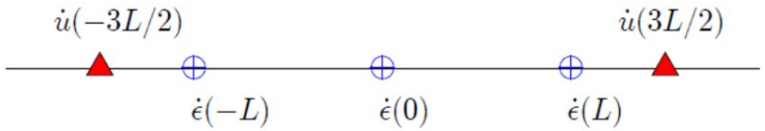
Geophones (red triangles) centered within a DAS segment

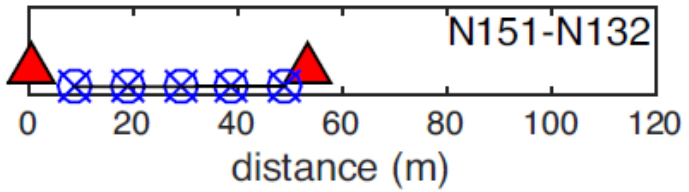
“Finite Difference” Relation between Sum of DAS Channels Nodals at End Points

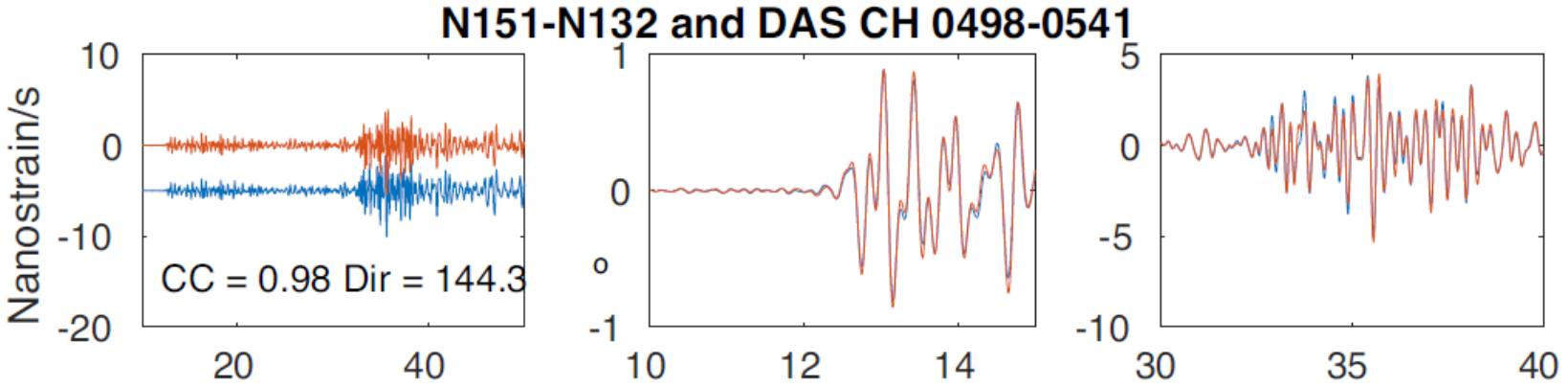
$$\dot{\varepsilon}_{DAS}(x) = \frac{1}{L}\int_{x-\frac{L}{2}}^{x+\frac{L}{2}} \dot{\varepsilon}(l)dl = \frac{\dot{u}\left(x+\frac{L}{2}\right) - \dot{u}\left(x-\frac{L}{2}\right)}{L}$$



$$\dot{\varepsilon}(-L) + \dot{\varepsilon}(0) + \dot{\varepsilon}(L) = \frac{\dot{u}\left(\frac{3L}{2}\right) - \dot{u}\left(-\frac{3L}{2}\right)}{L}$$





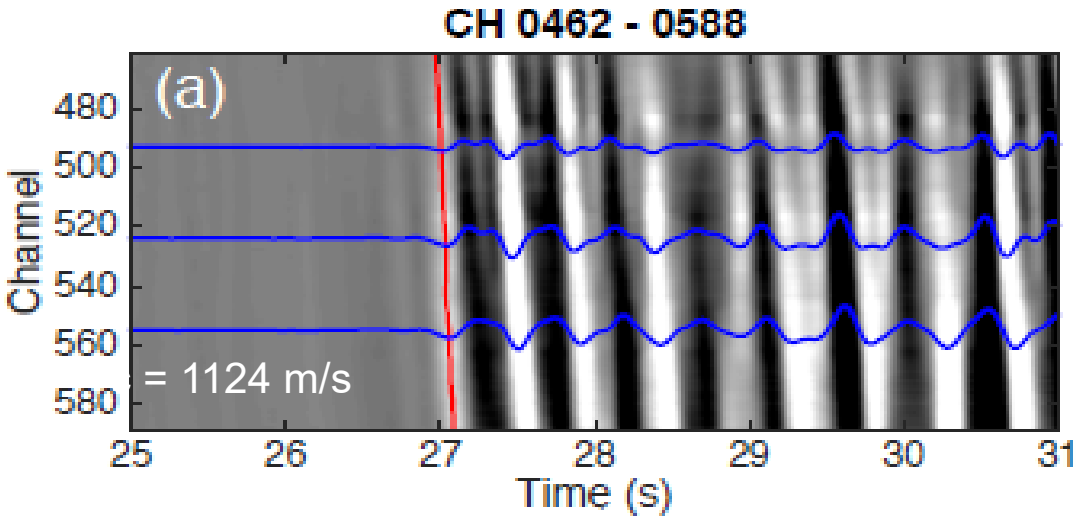


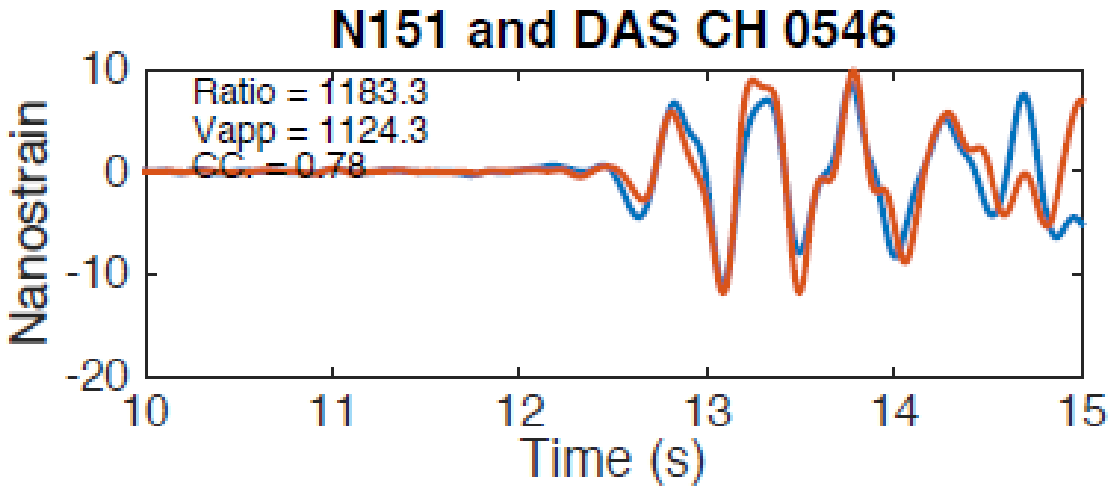
Wang, et al., (2018), GJI, 213 (3), 2020–2036.

DAS as Virtual Geophone

$$\epsilon = \frac{\partial u}{\partial x} = \pm \frac{1}{c}\frac{\partial u}{\partial t} = \pm \frac{1}{c}\dot{u}$$

Benioff (1932) and
Mikumo and Aki (1964)

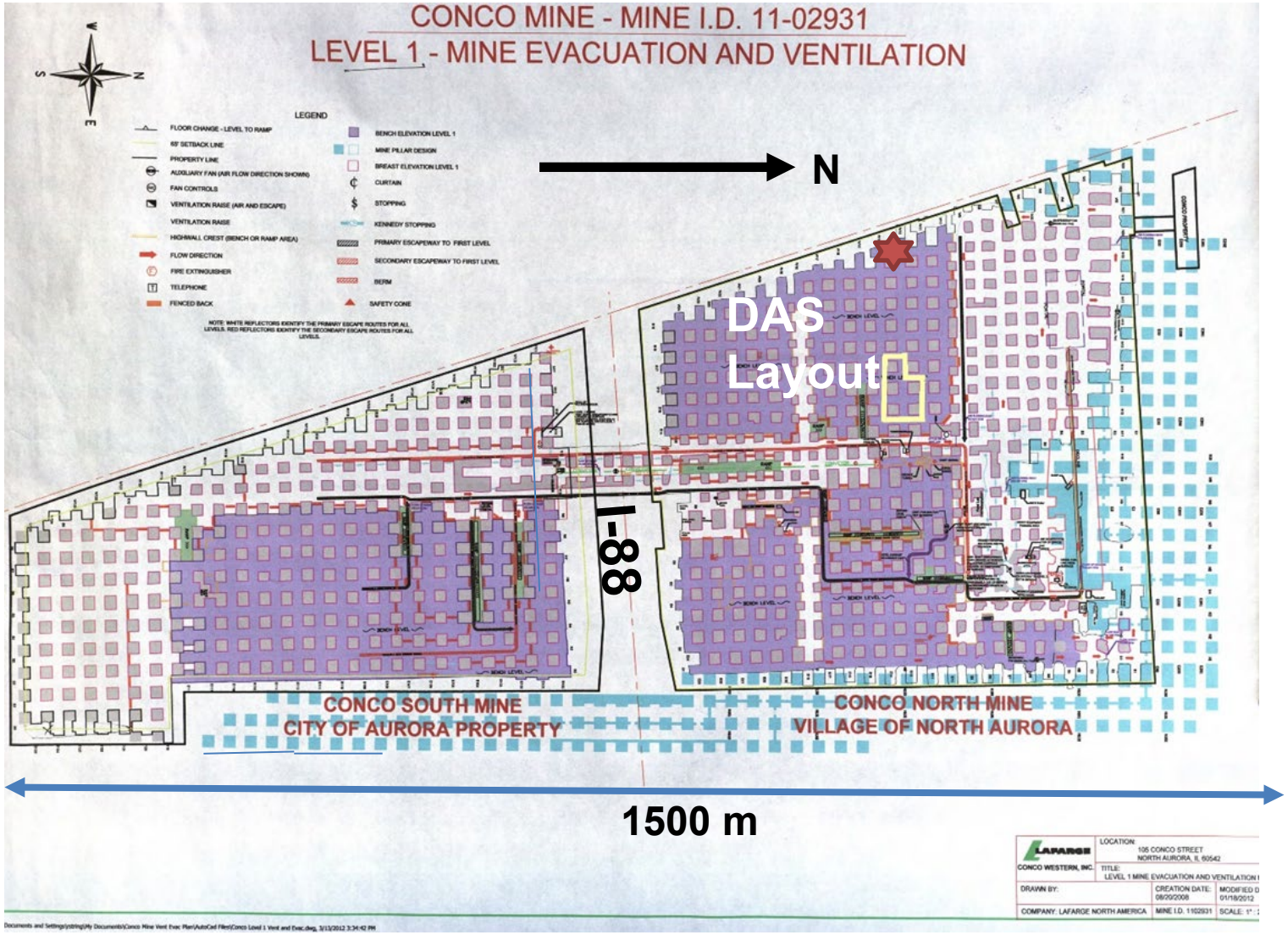




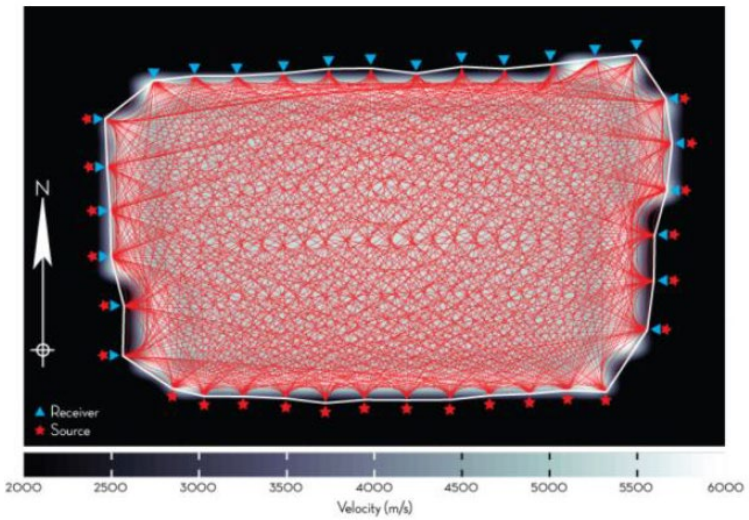
Lafarge-Conco Mine, N. Aurora, Illinois: 250-m array

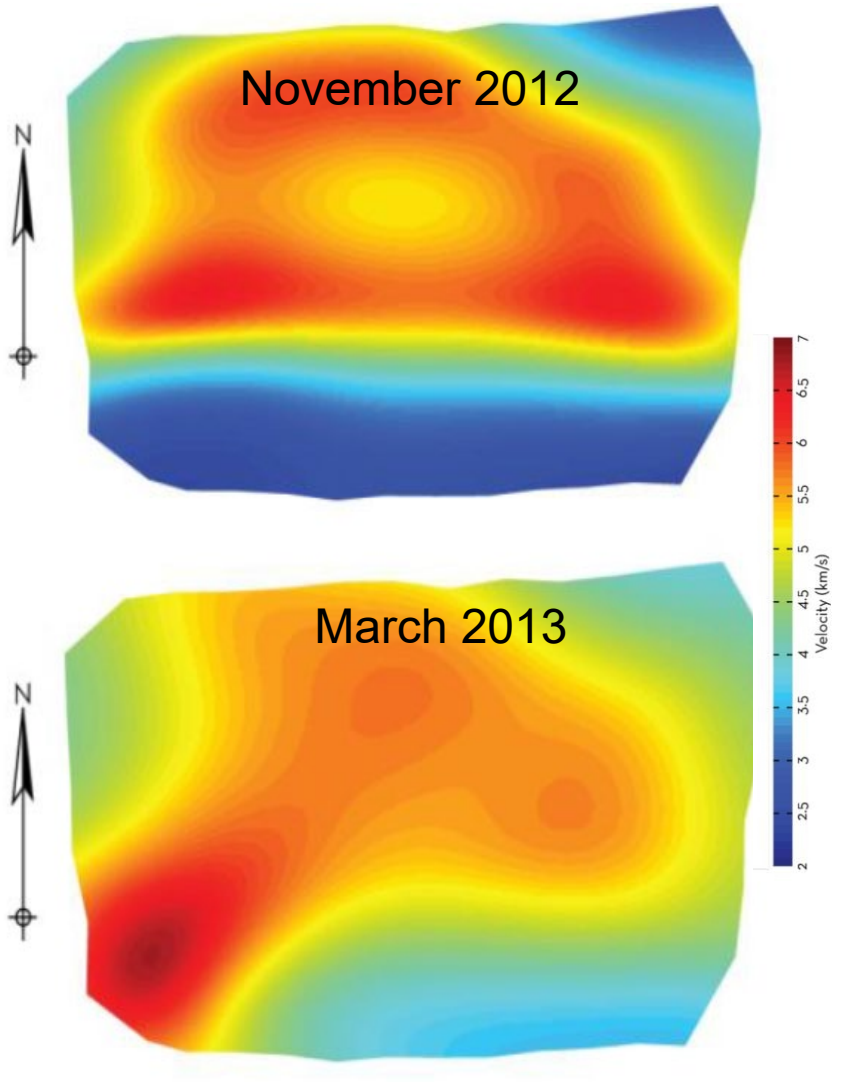
Mine Layout

- Room-and-pillar 1500-m long x 500-m wide at I-88.
- Ordovician limestone and dolomite.
- Four levels down to a depth of about 80 m.
- Background noise from mine truck traffic and conveyer belts was present during our experiment except when the mine was cleared for blasting.



Seismic Velocity in Pillars Increase after Excavations

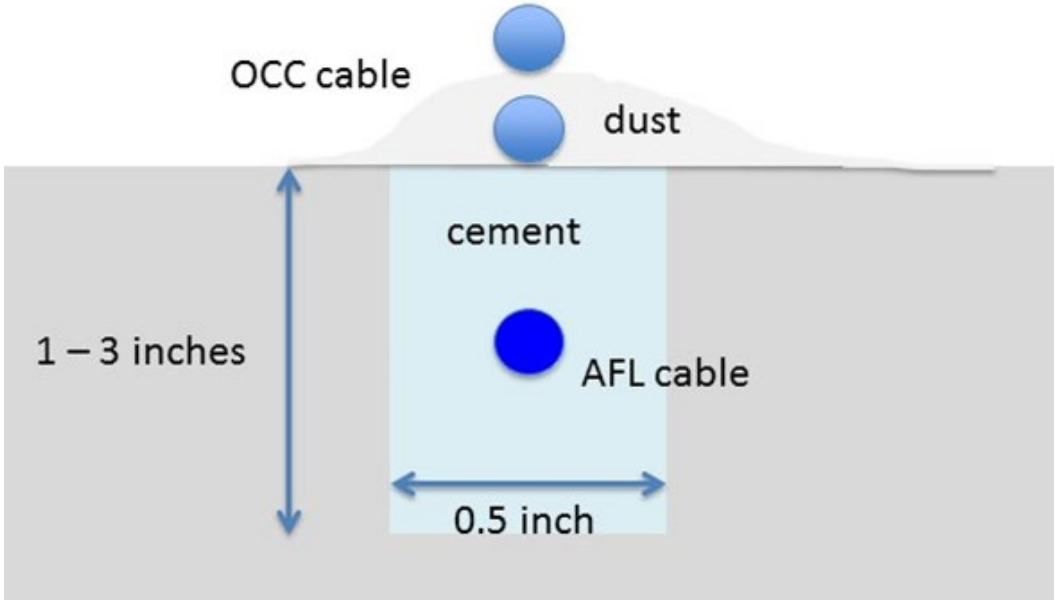




- **Study pillar** 13.5 m by 22.5 m by 8 m high.
- **Hammer source** with 24 geophone receivers on three sides of the pillar.
- **576 source-to-receiver** ray paths.
- **Excavation** almost **directly below study pillar**.
- **Average velocity increases 700 m/s** between Nov. 2012 and March 2013

Meulemans, Fratta, Wang (2015)

DAS Cable Installation

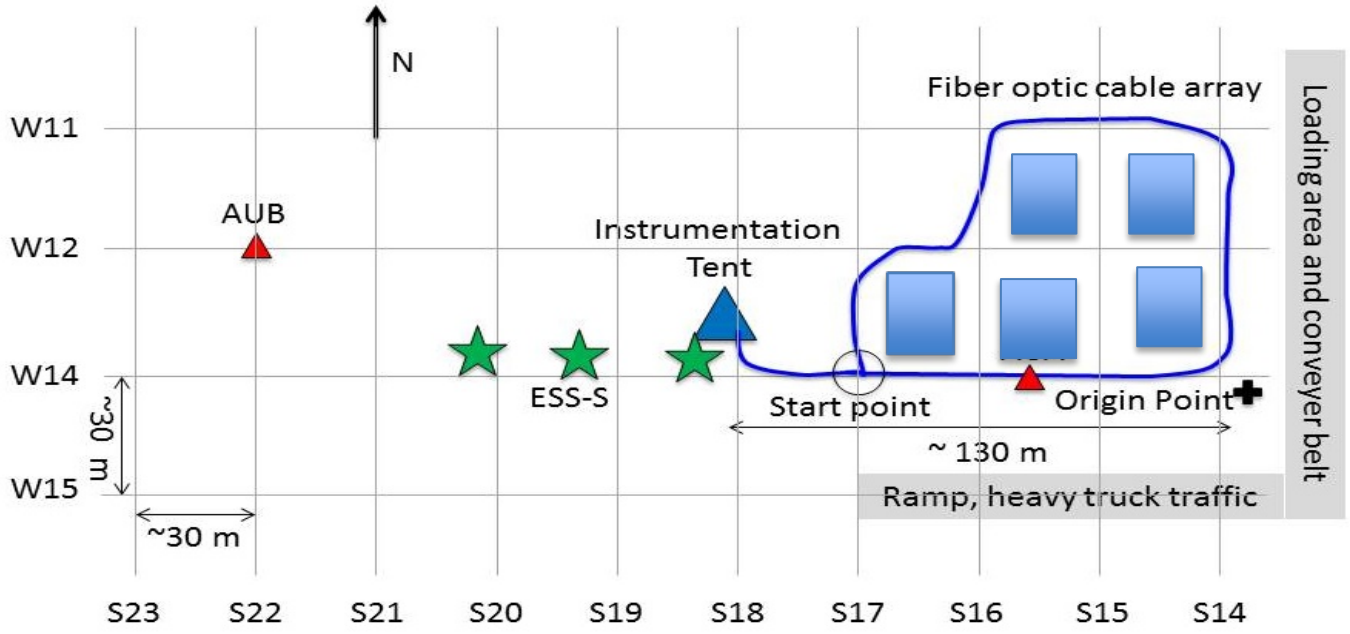


Pavement saw cut groove 1.2-cm wide and about 5-cm deep. Total path length was about 250 meters.

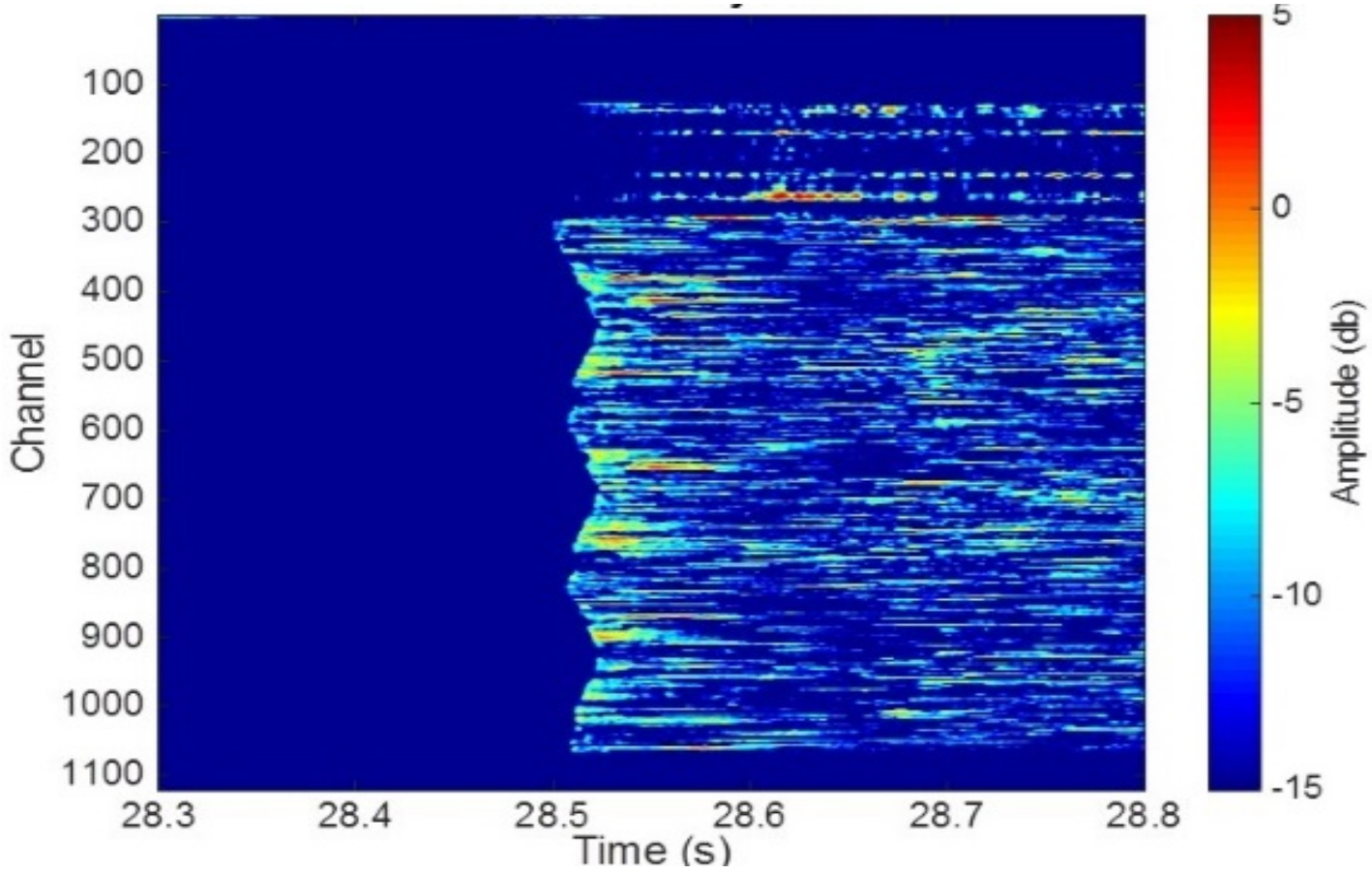
Three co-located layers of fiber-optic cable were installed. Total cable length was about 750 meters.

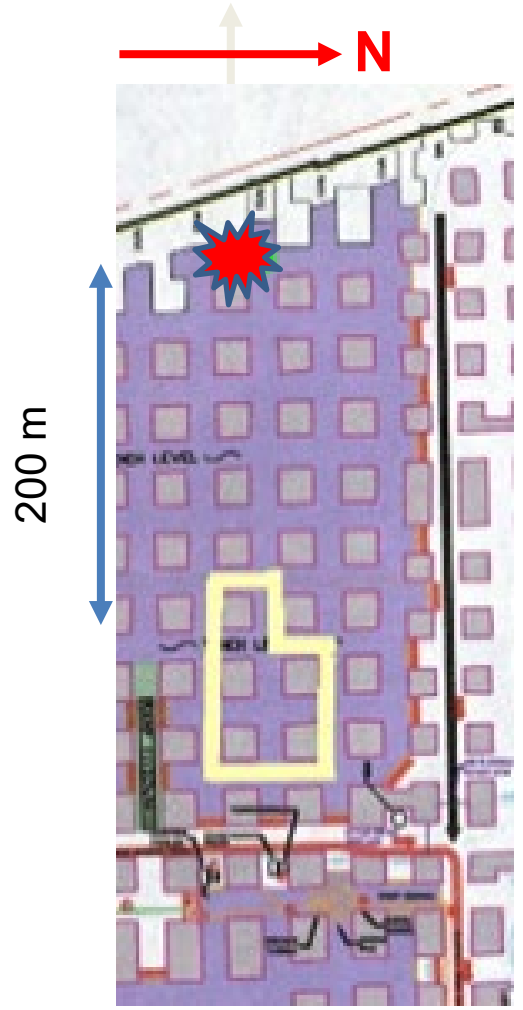
- First cable (AFL brand) was cemented in groove.
- Middle cable (OCC brand) was placed above cemented cable and covered with fine rock powder.
- Top cable was placed without cover.

Experimental Layout



Blast Results for July 28, 2017 15:46.47.85





DAS and Data-Cube data (10 GB) archived at go.wisc.edu/ac7634.

Zeng, et al., (2020). AGU special issue on Distributed Acoustic Sensing

Summary

- DAS is spatially dense, large N, seismic array.
- DAS can be used for near-surface geotechnical work, earthquake seismology, traffic monitoring, infrastructure monitoring, intrusion detection, mine monitoring.
- DAS needs coupling to the ground, but cable could be part of road or rail infrastructure during construction or DAS can be used on dark fiber.