# Distributed acoustic sensing for seismic monitoring in challenging environments

Zack Spica

With a lot of inputs from:

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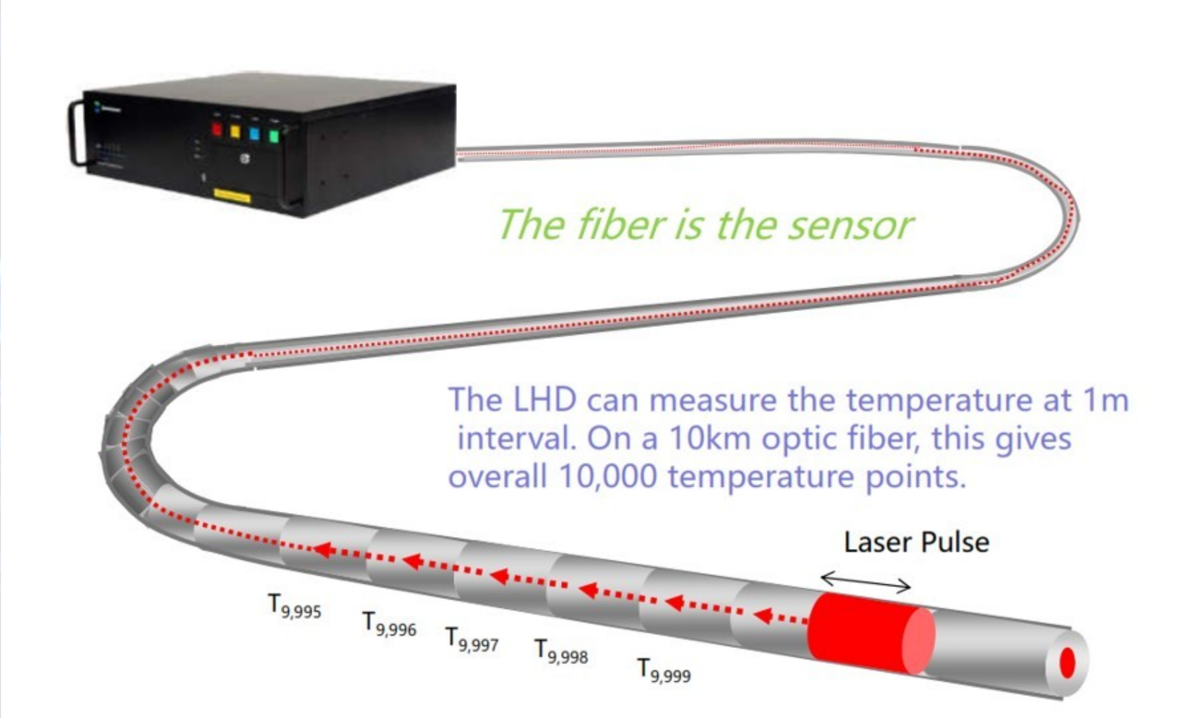
# Distributed Acoustic Sensing (DAS)

can transform existing telecommunication fiber-optic cables into arrays of thousands of sensors, enabling meter-scale recording over tens of kilometers of linear fiber length.

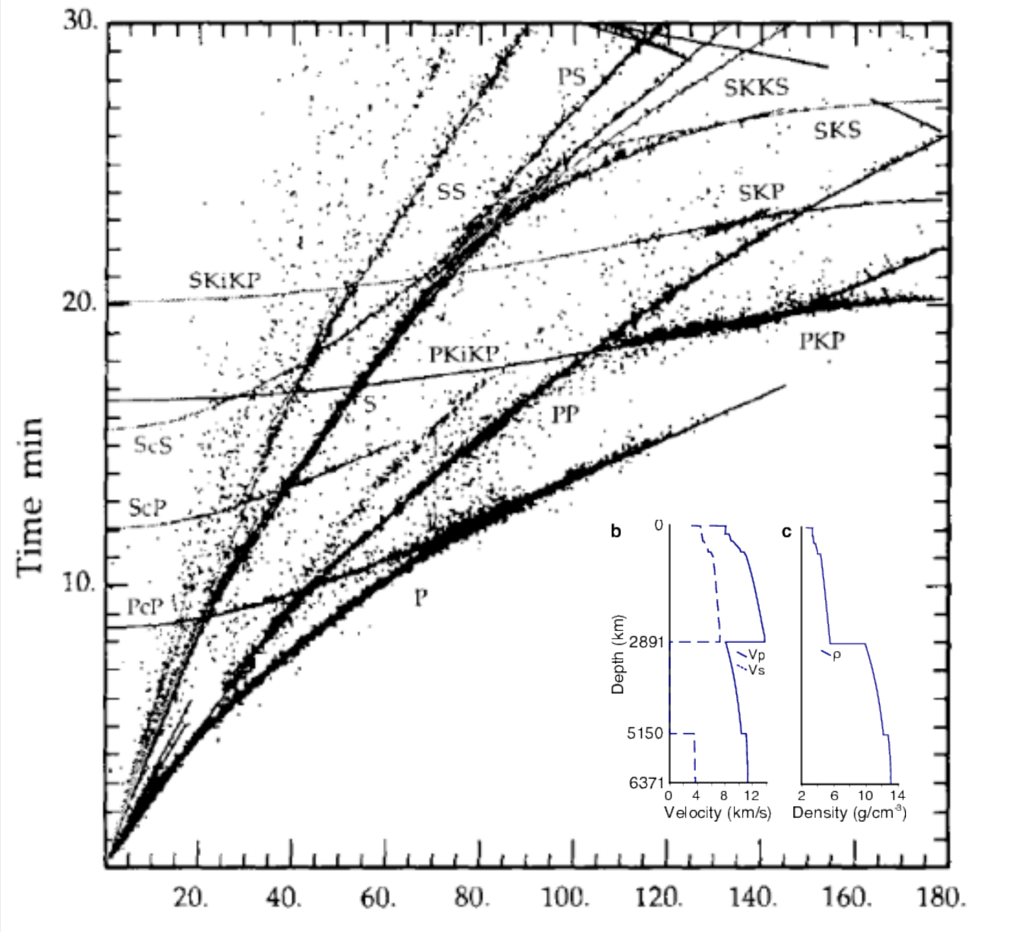
Fiber can operate at high temperature and high pressure which is ideal for a variety of environments such as:

- Active volcano
- Deep borehole
- Ocean-bottom
- Busy cities



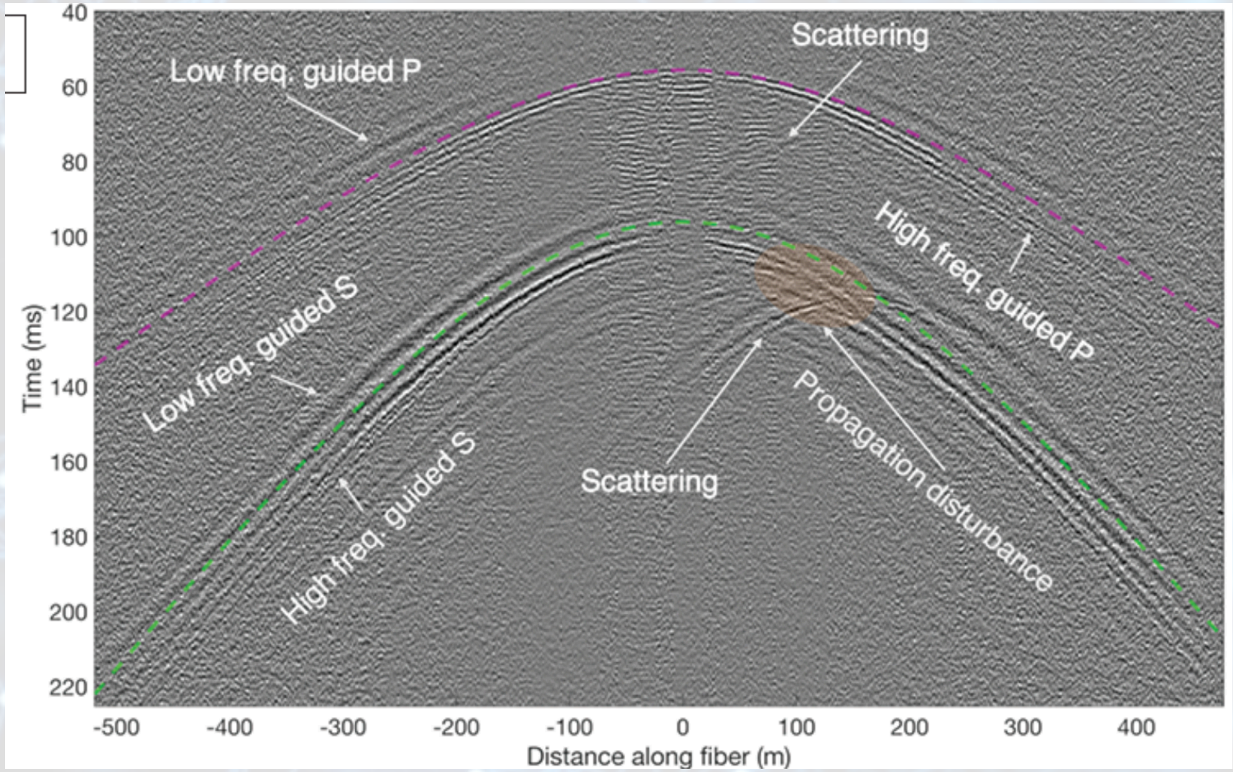

https://www.ienergy.com.sg/

## Traditional global array seismology




Kennett and Engdahl 1991

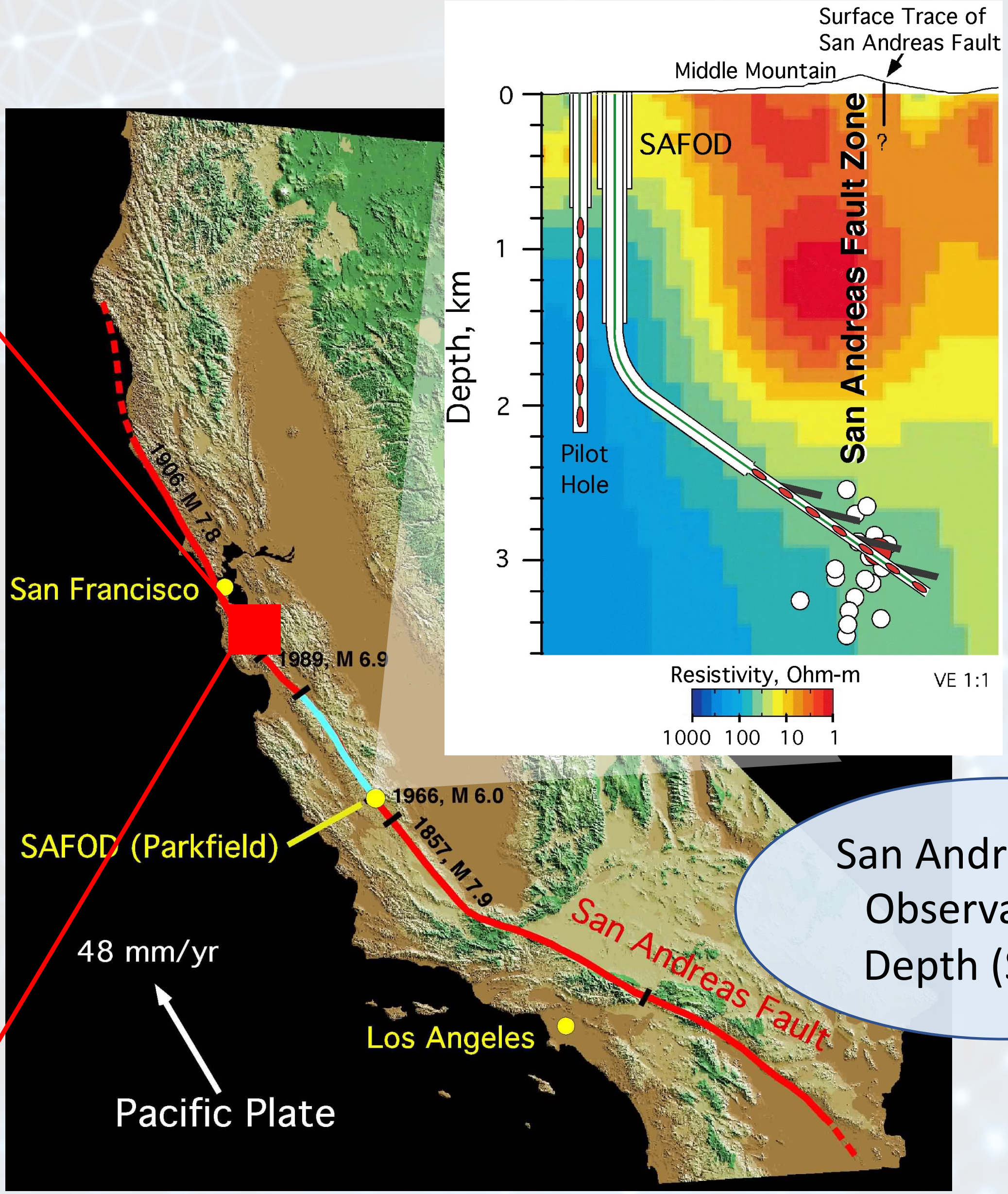
## DAS recording the full wavefield




Lellouch et al., 2019

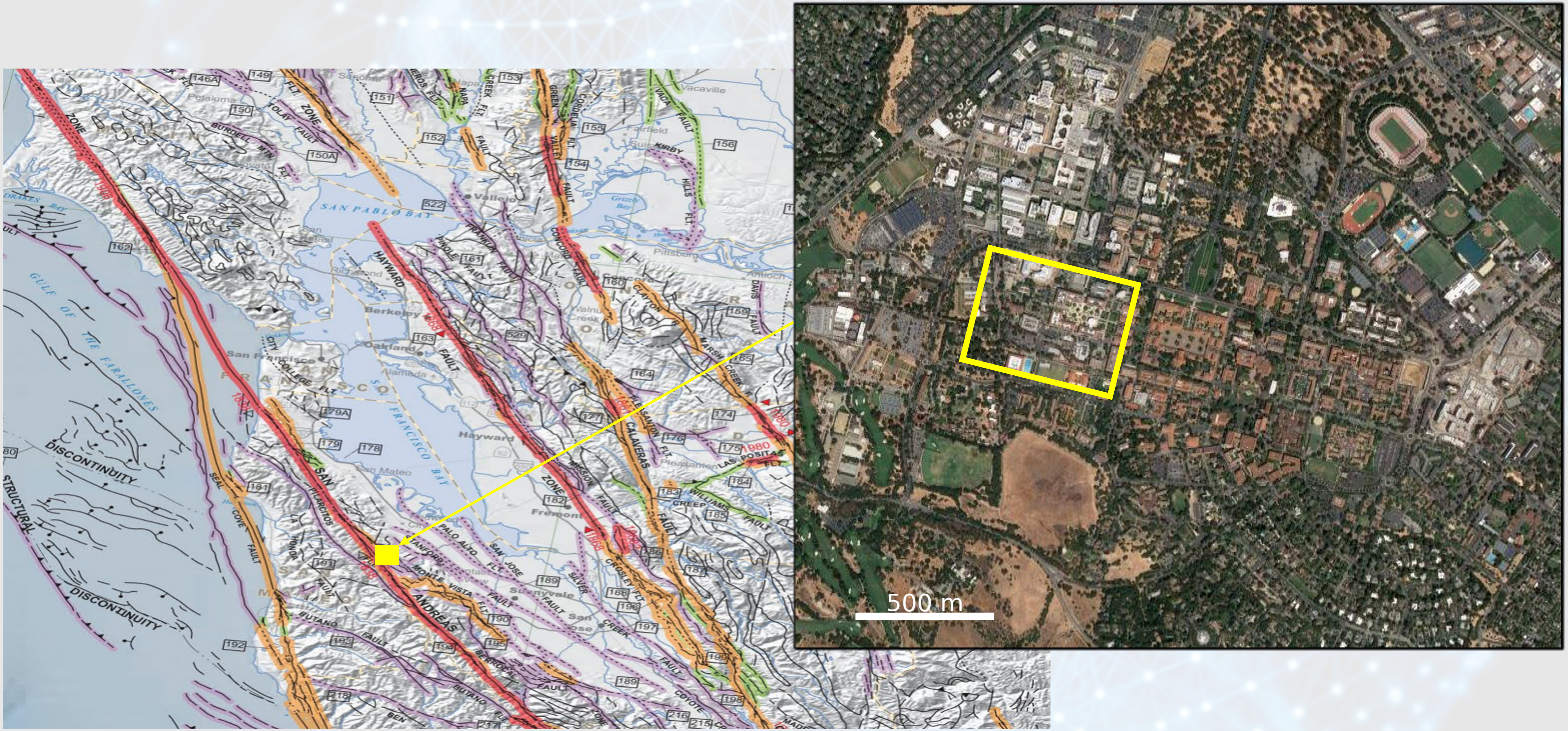
# Two permanent monitoring configurations

Stanford Array

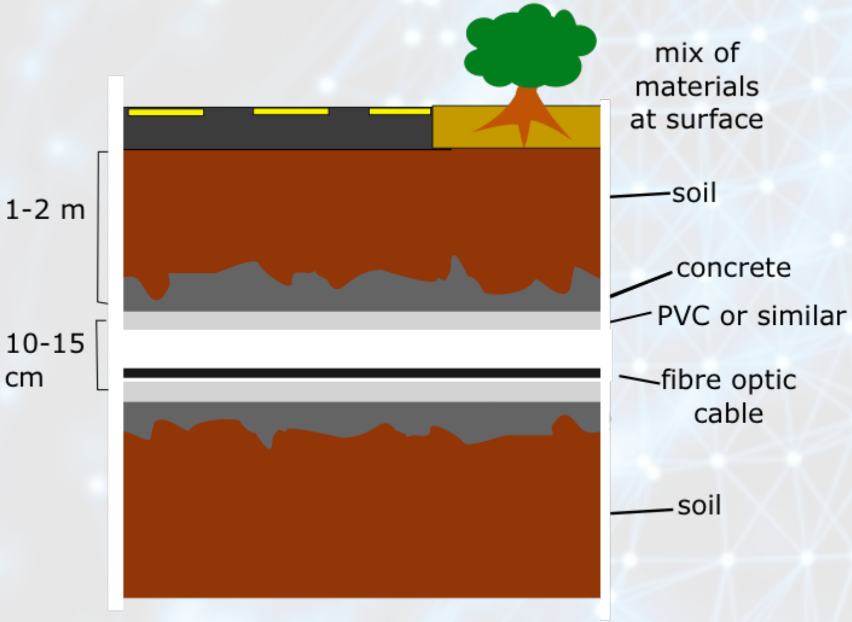



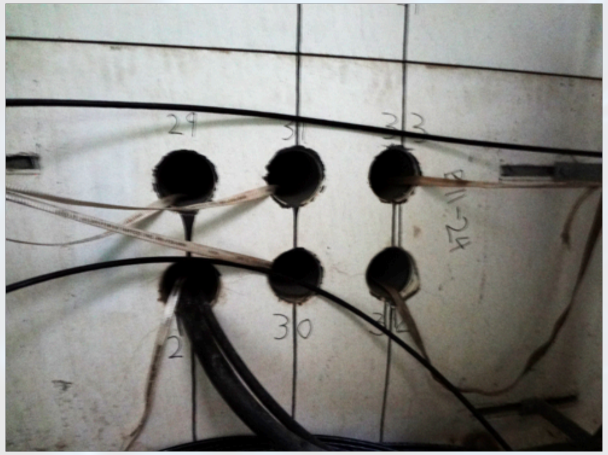

San Andreas Fault Observatory at Depth (SAFOD)

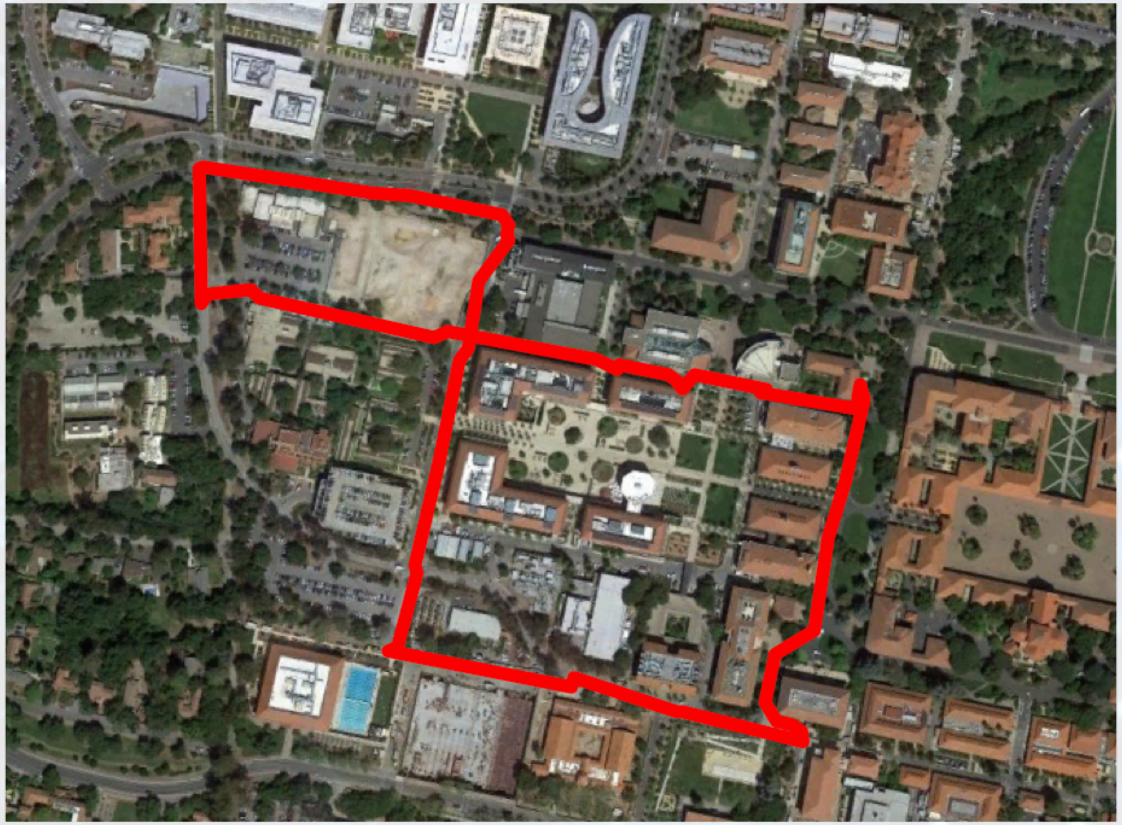
# The Stanford DAS array



# Array deployment

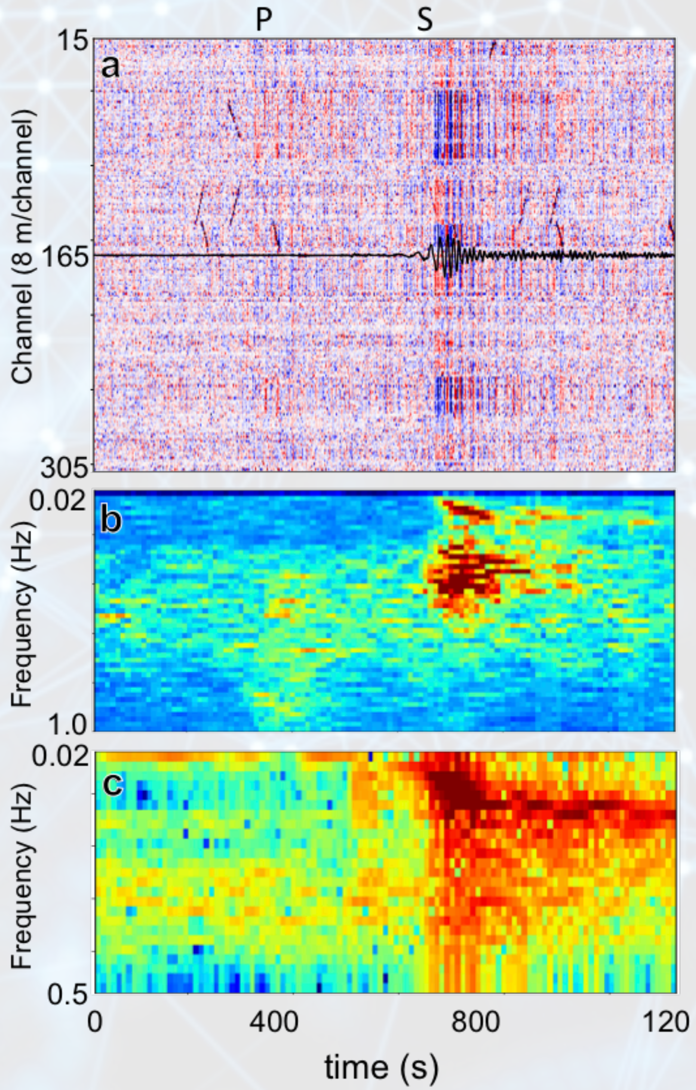




# We recorded earthquakes, near and far

M 5.8 earthquake
Pawnee, OK
September 2016

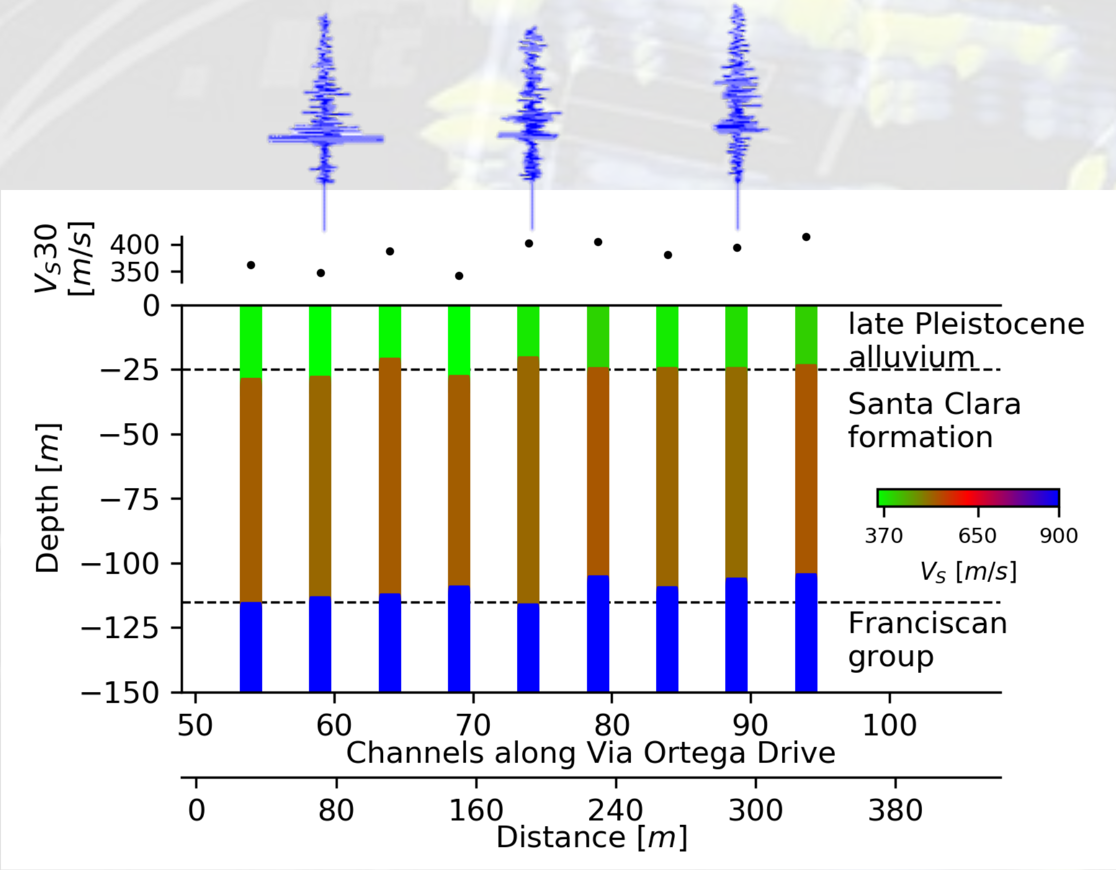

**fiber array overlaid with seismometer**

**fiber sensors**
sliding window
log spectrum

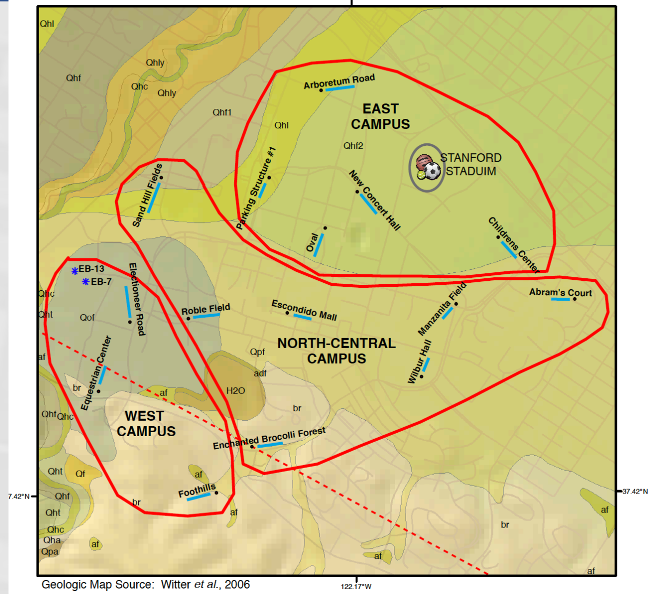
**seismometer**
sliding window
log spectrum

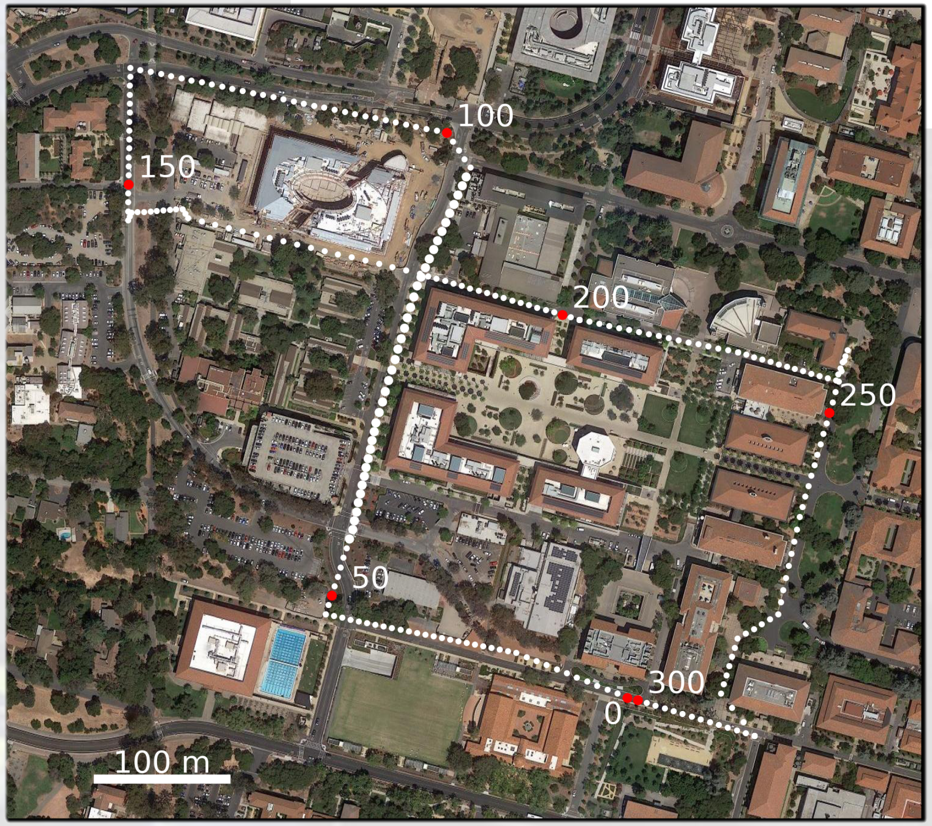
**What we learned:**
we get reasonable arrival times over a range of frequencies.

Lindsey et al., 2017



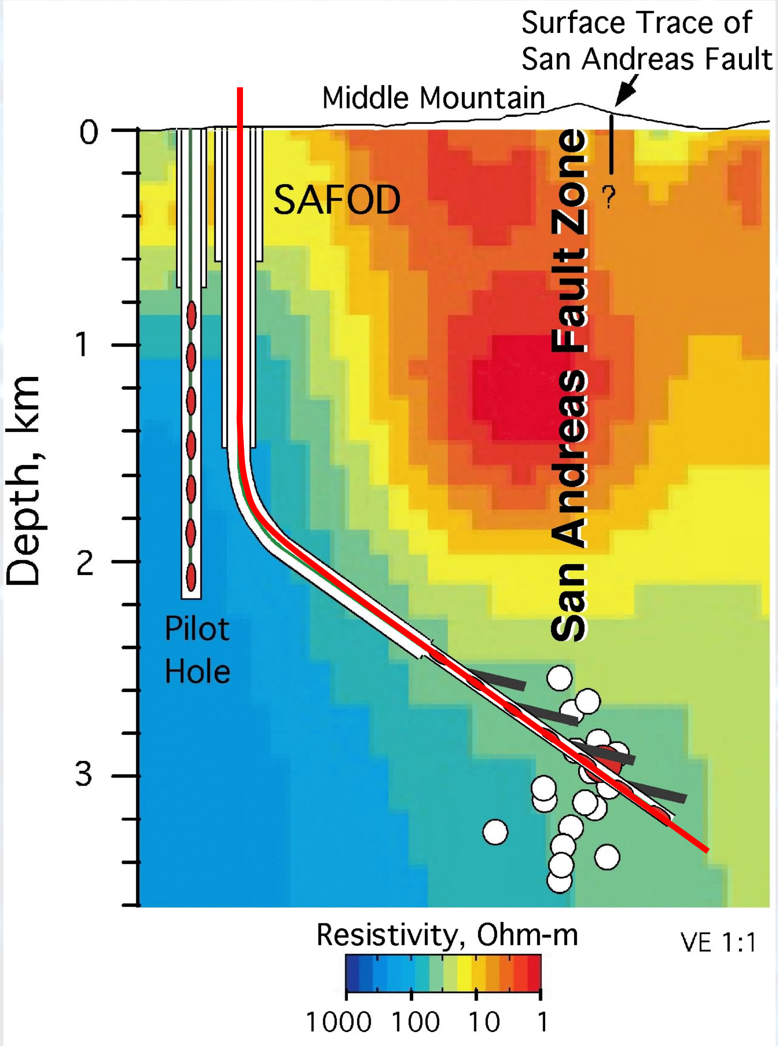

Spica et al., 2020

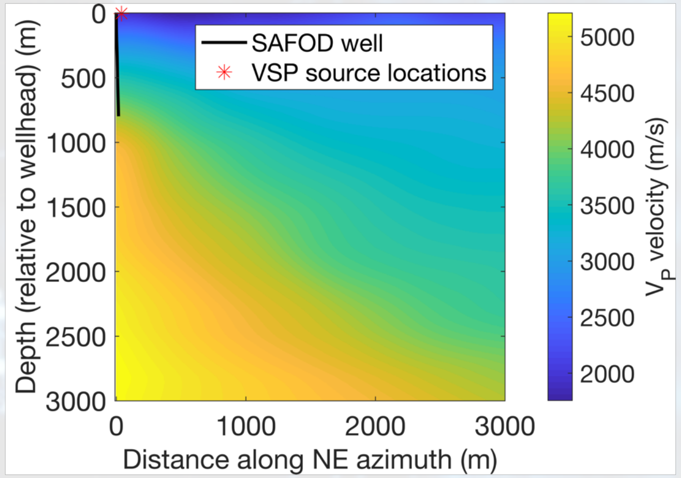



# Site-specific seismic hazard assessment for Stanford main campus

# San Andreas Fault Observatory at Depth (SAFOD)

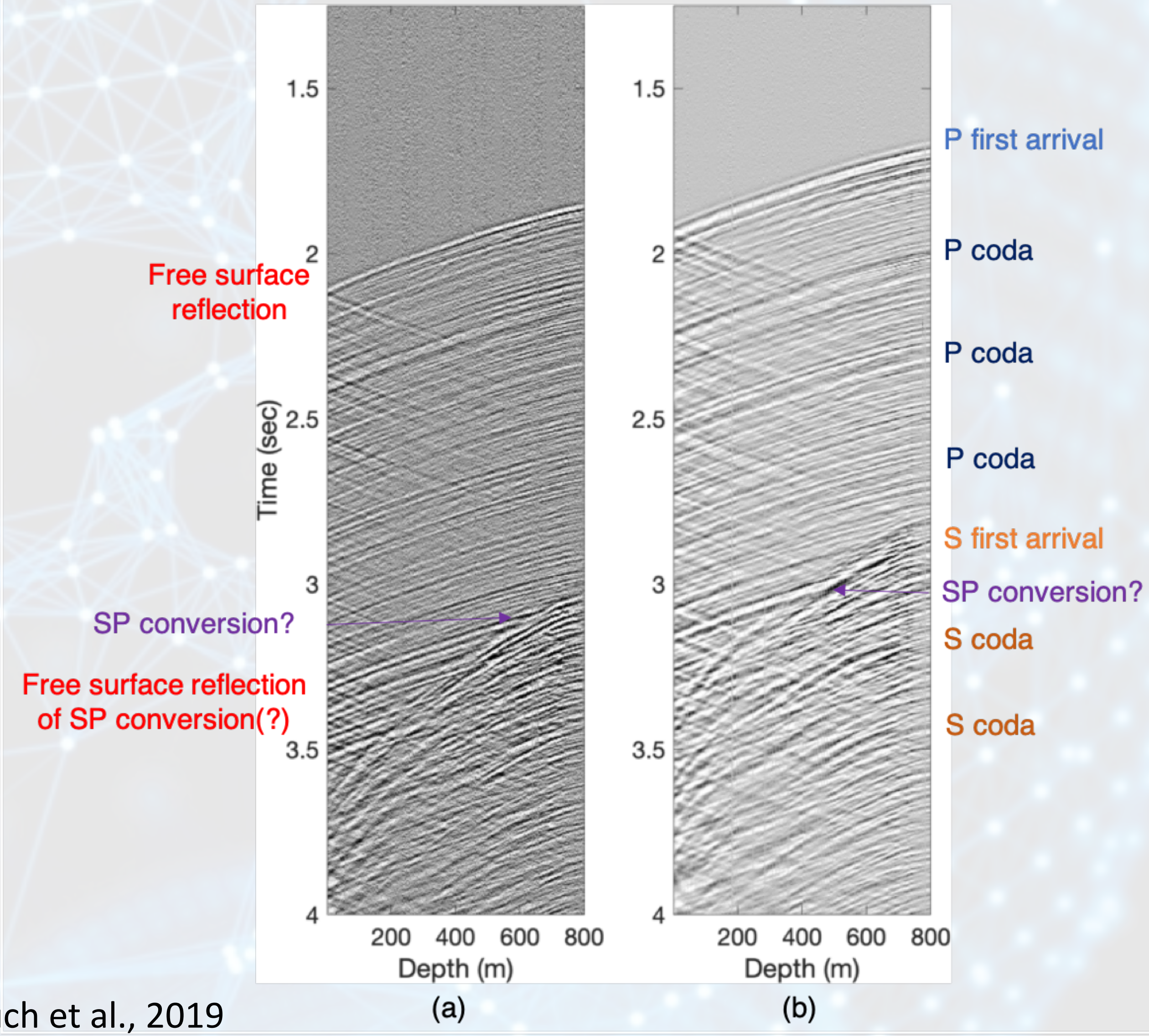




*The central scientific objective of SAFOD is to directly measure the physical and chemical processes that control deformation and earthquake generation within an active plate-bounding fault zone.*

# Near-vertical earthquakes for velocity analysis

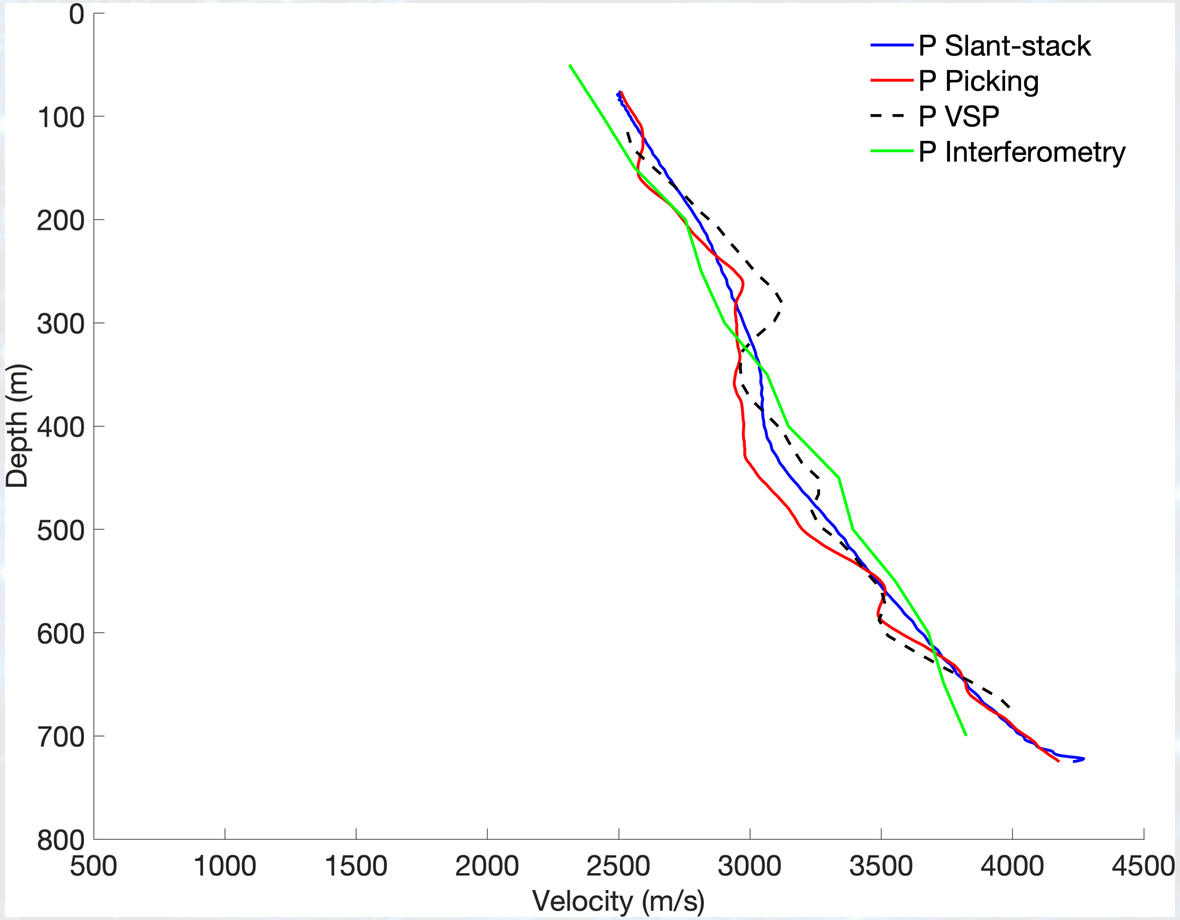
- Velocity increases with depth -> incidence angle tends to vertical
- Simple pre-processing
  - Median value removal
  - Down-sampling
  - Noisy channel auto-muting
- Visible, coherent first breaks
  - Coda waves have similar moveout
- S arrivals are harder to separate
  - Converted modes?
  - Interference with P coda waves?




Lellouch et al., 2019

# Estimated velocities near SAFOD using DAS techniques

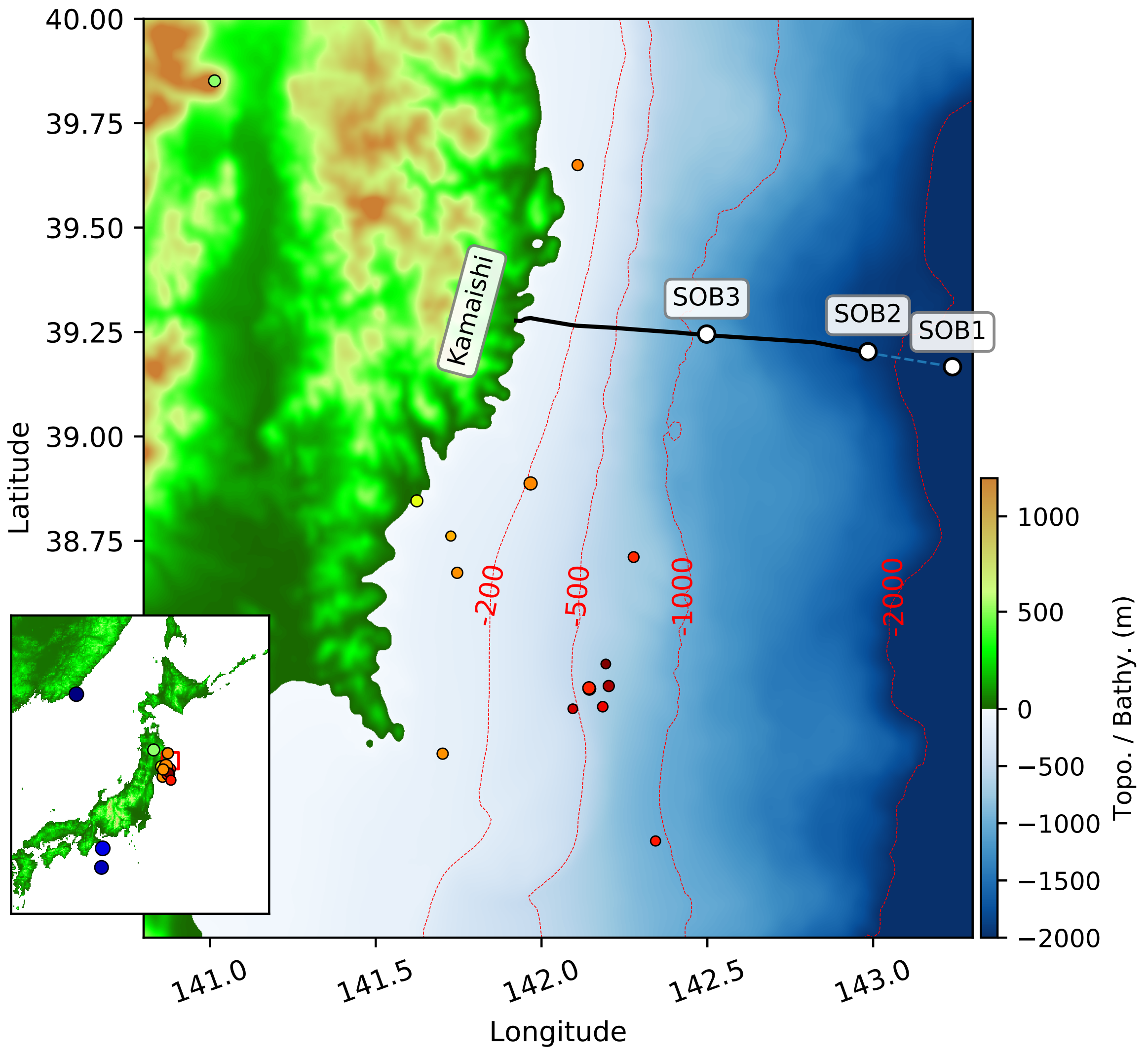
- Good agreement between picking and slant-stacks
- Matches check-shot processing
- Interferometry

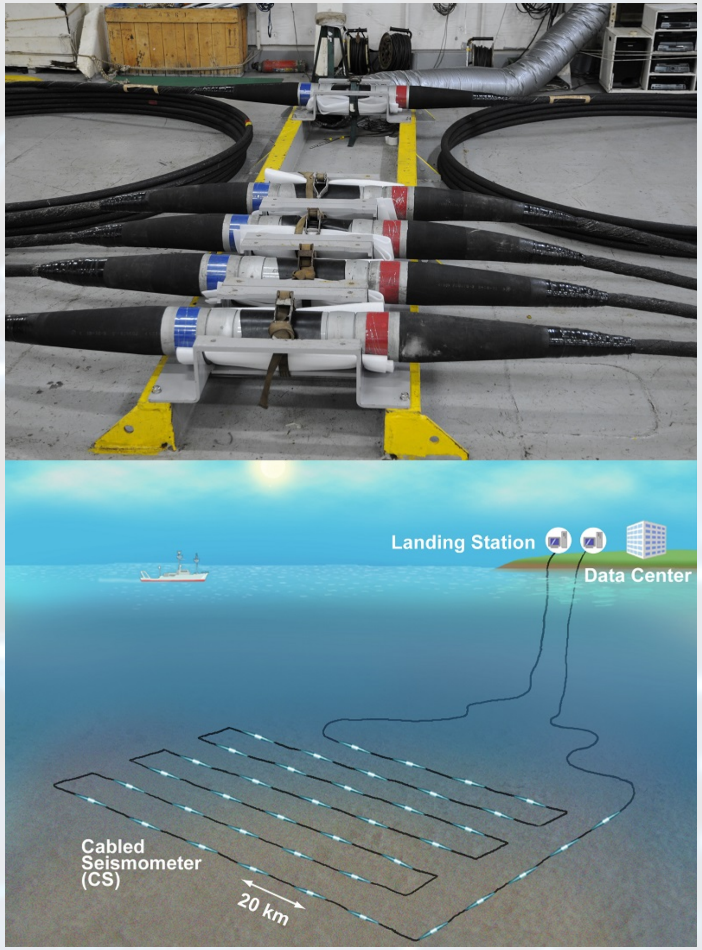



Lellouch et al., 2019

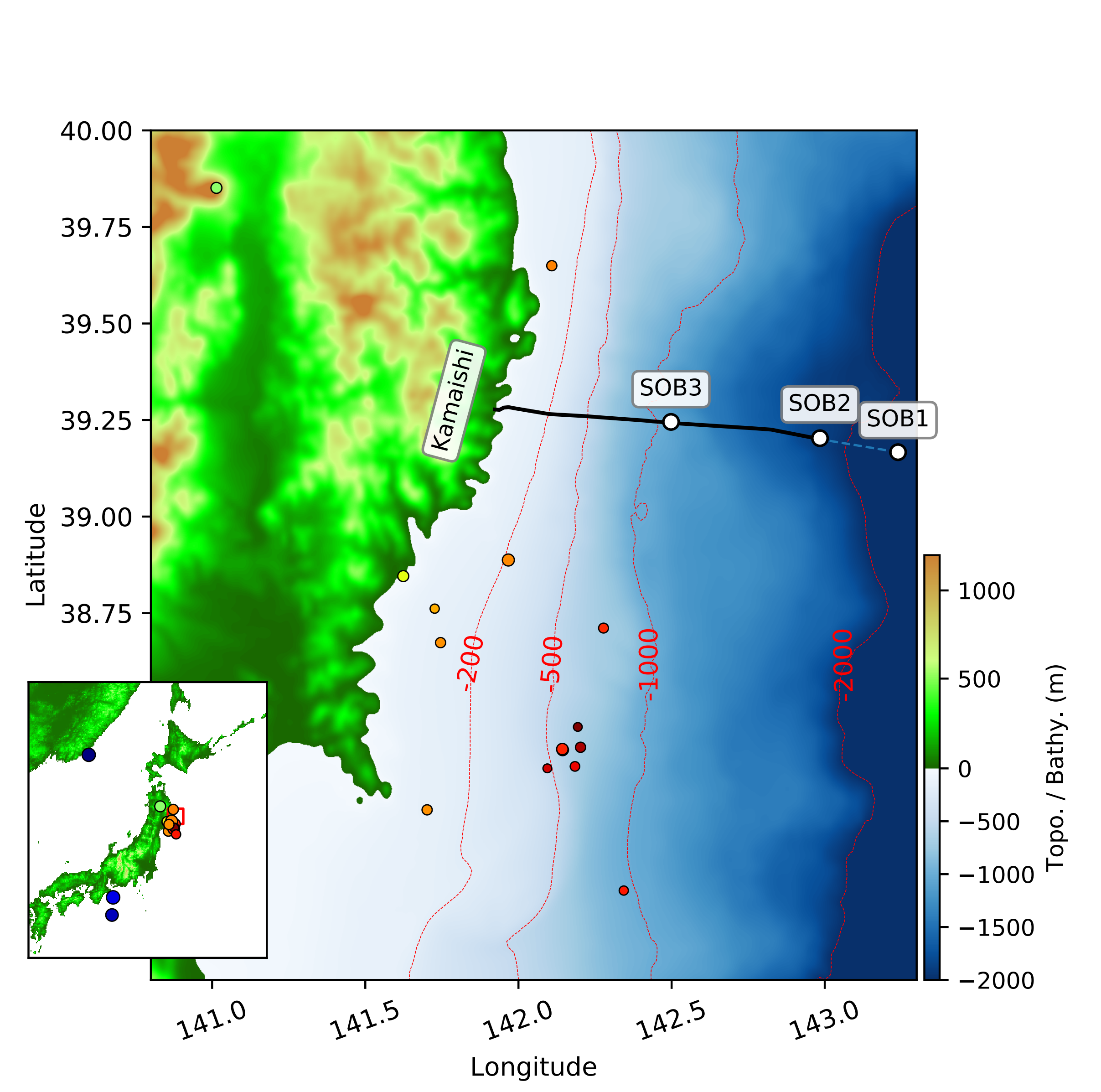
# Ocean-bottom observation in the Sanriku region

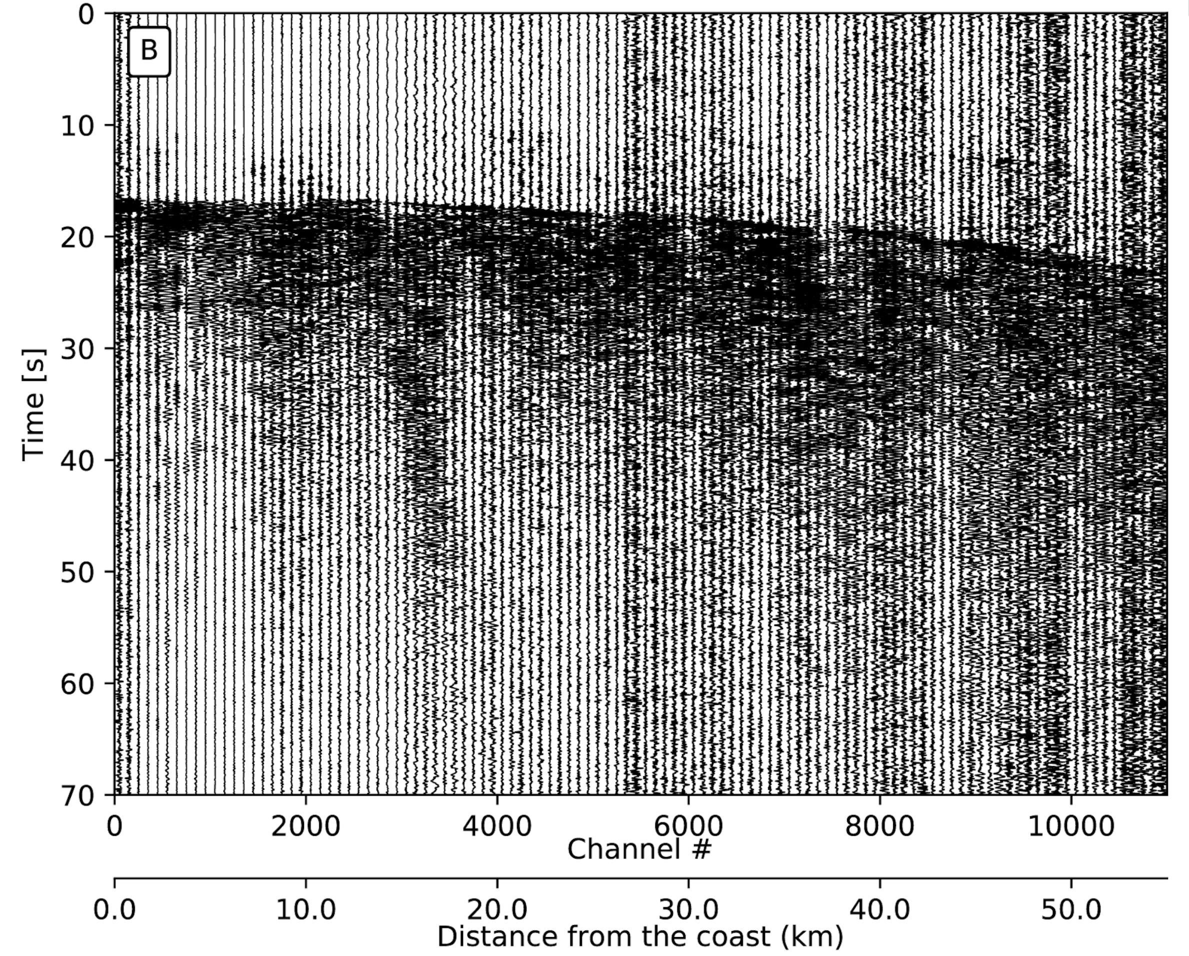
Project led by M. Shinohara



# Ocean-bottom observation of earthquakes



# Future applications of passive dark fiber

- Imaging for earthquake hazard analysis
- Permafrost thaw monitoring
- Volcano monitoring through seismicity
- Early earthquake warning
- Induced seismicity location/detection at community scale
- Detecting infrastructure problems (broken water mains, sinkholes, potholes, railway misalignment)