

# Low-Frequency Seismicity Recorded at CO<sub>2</sub> Injection Sites

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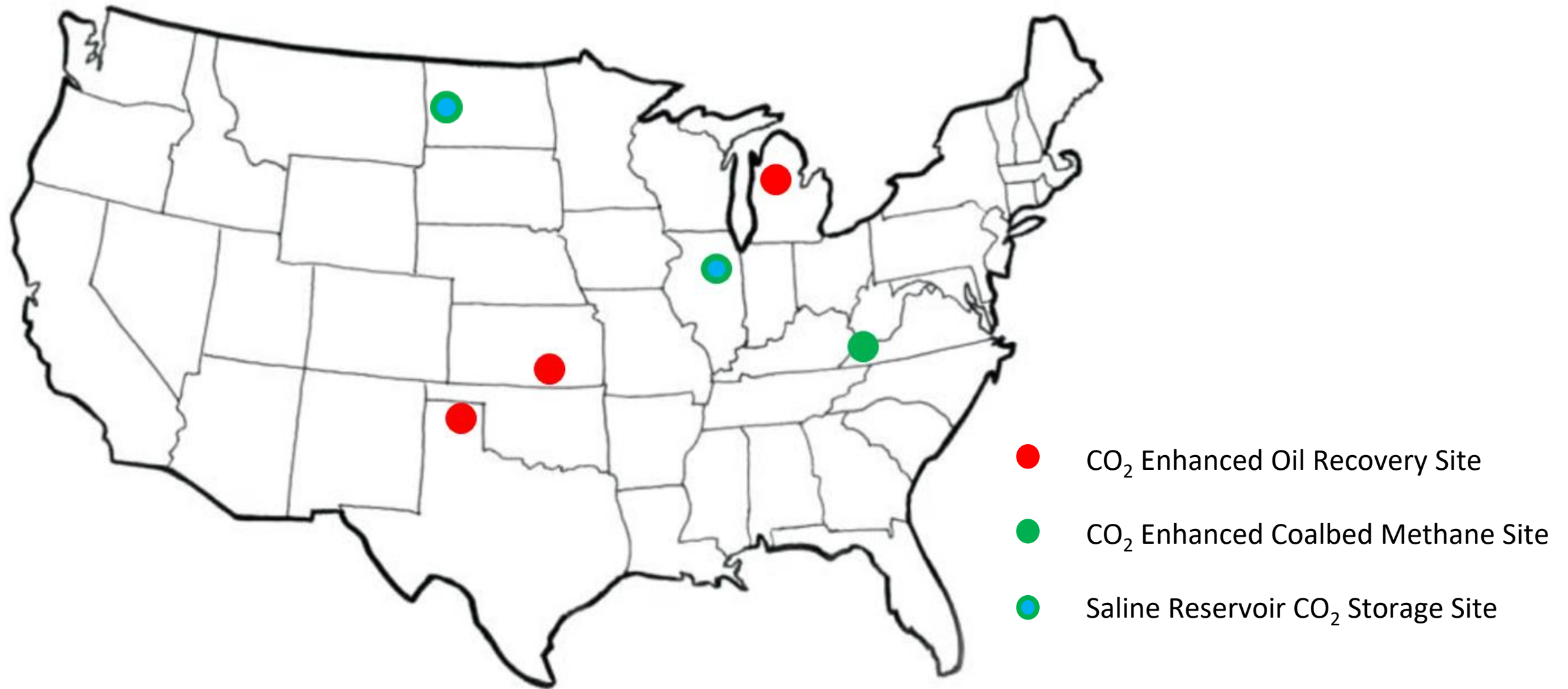
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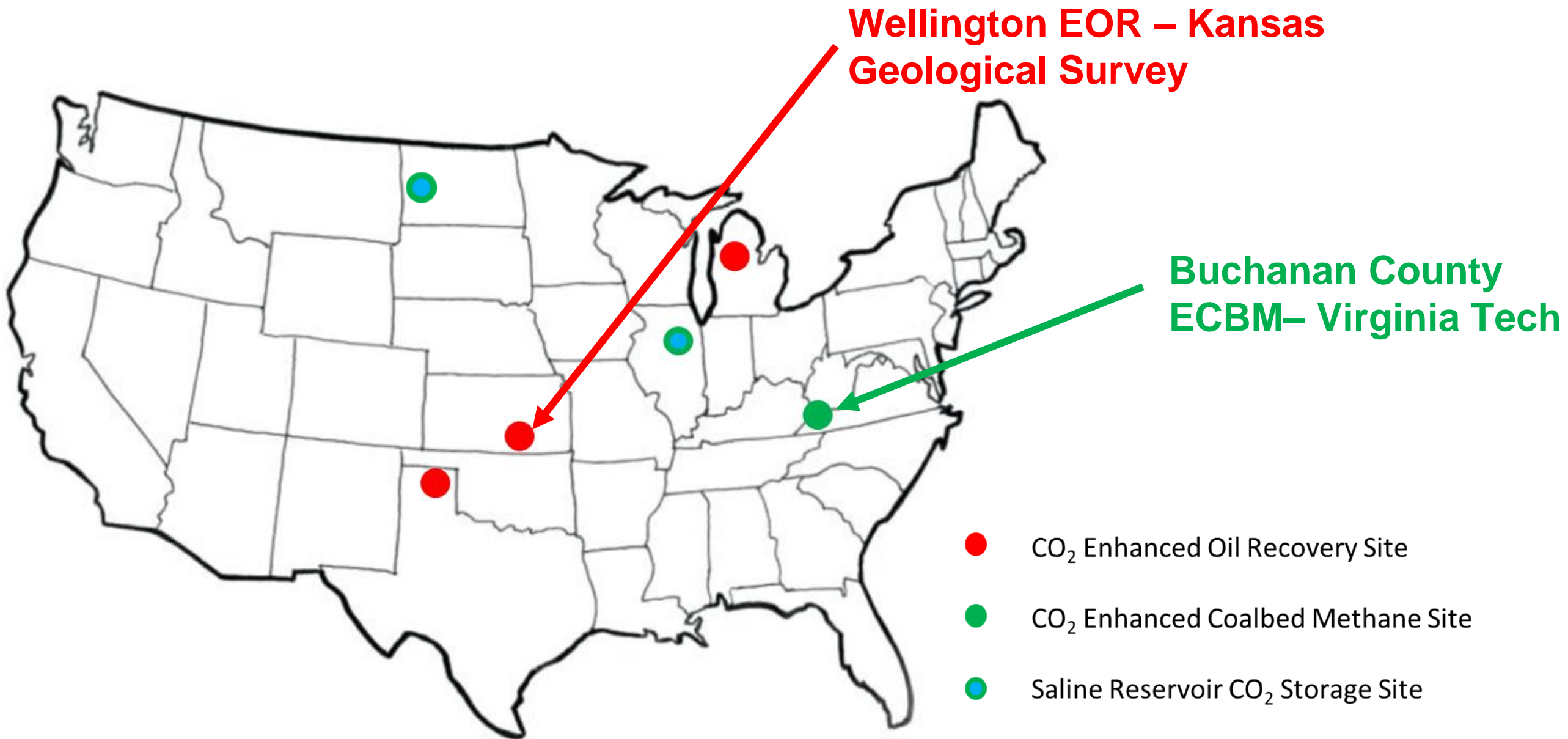
U.S. DEPARTMENT OF  
**ENERGY**



# Seismic Data Sets from CO<sub>2</sub> Injection Sites



# Seismic Data Sets from CO<sub>2</sub> Injection Sites





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## Tremor signals during fluid injection are generated by fault slip

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↓ 1,437



### Editor's summary

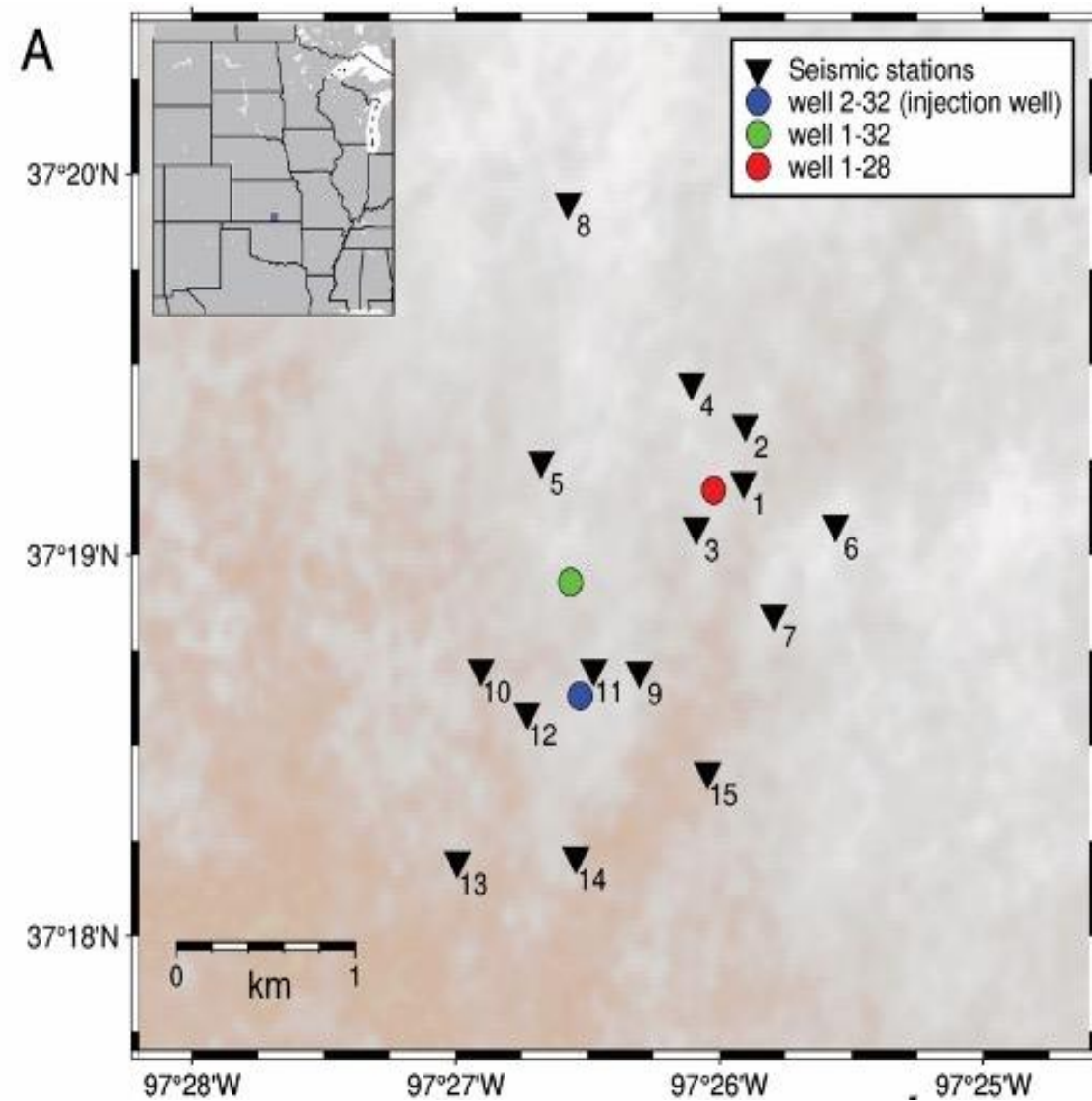
Volcanoes and glaciers have seismic tremors that are caused by fluid movement or other frictional processes. Niyogi *et al.* found that tremors with very similar characteristics also occurred during a supercritical carbon dioxide injection program in Kansas. After carefully subtracting background noise, the authors found tremors located near fault structures in the interior that likely were due to frictional slip. This finding may provide a way to model and track stress distribution in the subsurface during the injection of carbon dioxide or other fluids. —Brent Grocholski





# Injection Site and Station Map

Wellington, Kansas



Niyogi et al., 2023

### IRIS Seismometer Installation

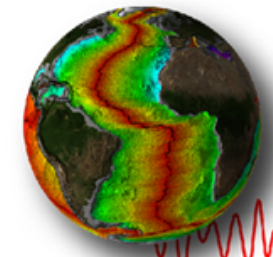
Housing setup for Sercel (Mark Products) L-22D-3D sensors, ~5 ft below surface to minimize surface noise; installed below frost line in bedrock

Shelby Peterie, KGS Exploration Services, checking installation in July 2014

**PASSCAL**  
Program for Array Seismic Studies of the Continental Lithosphere

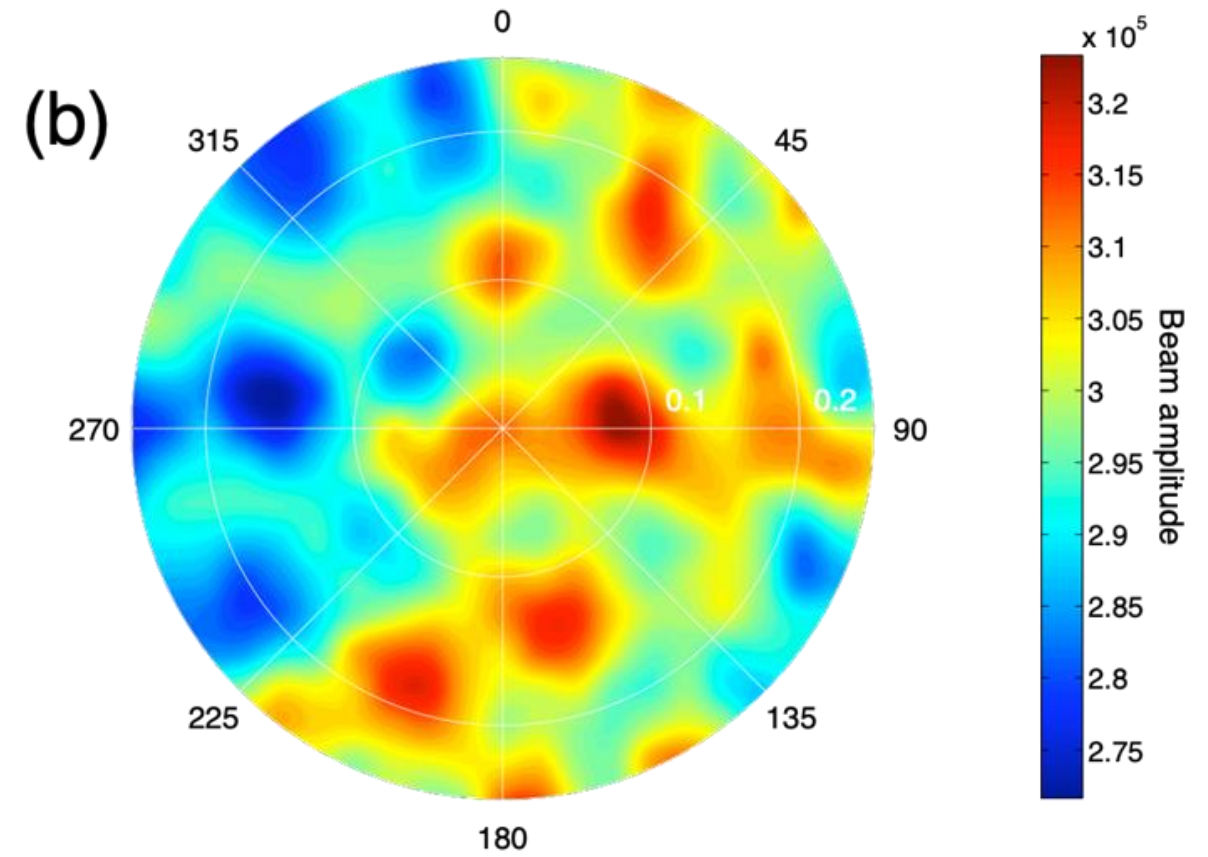
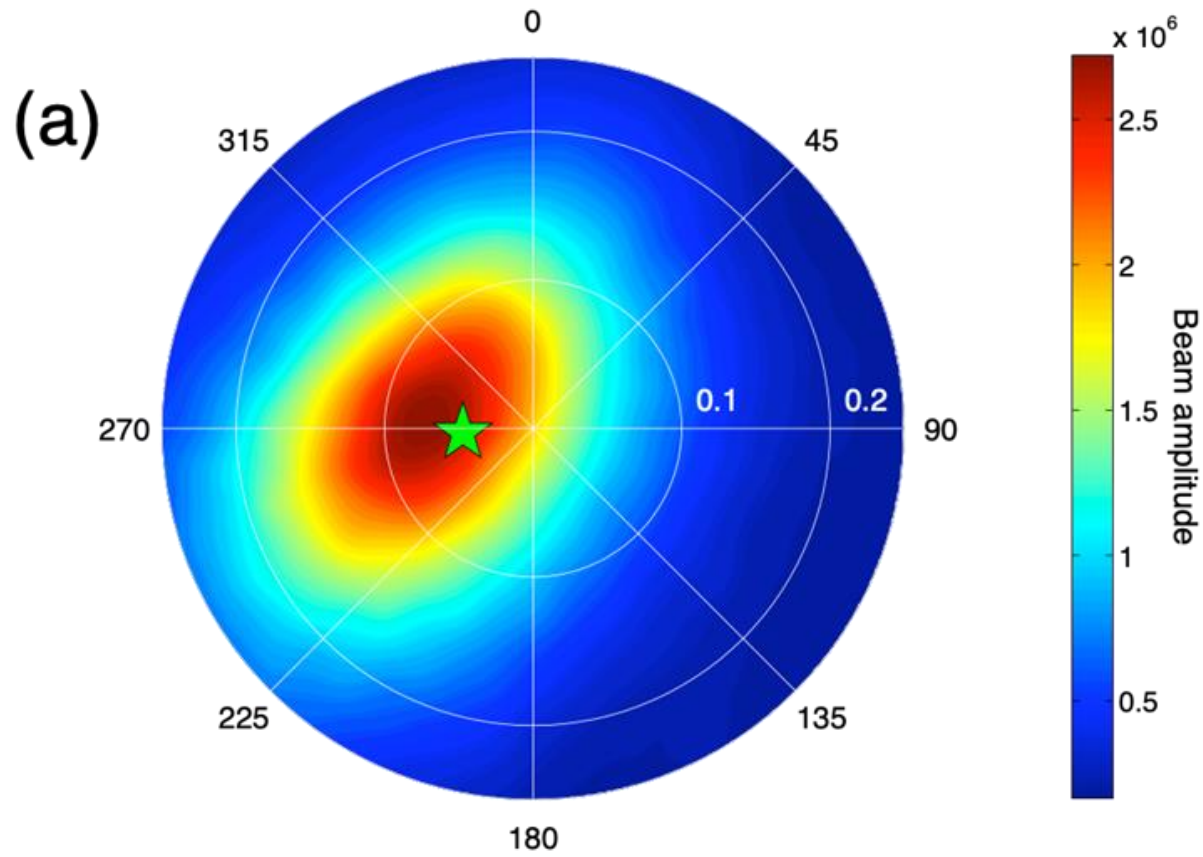
21  
R. Miller and S. Peterie, KGS

# Beamforming Tremor Signals



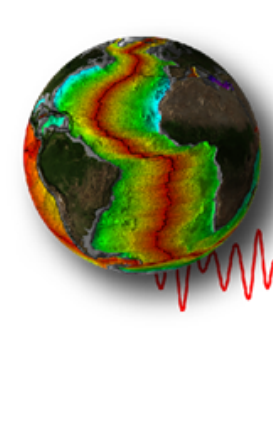
## Tremor

## Noise

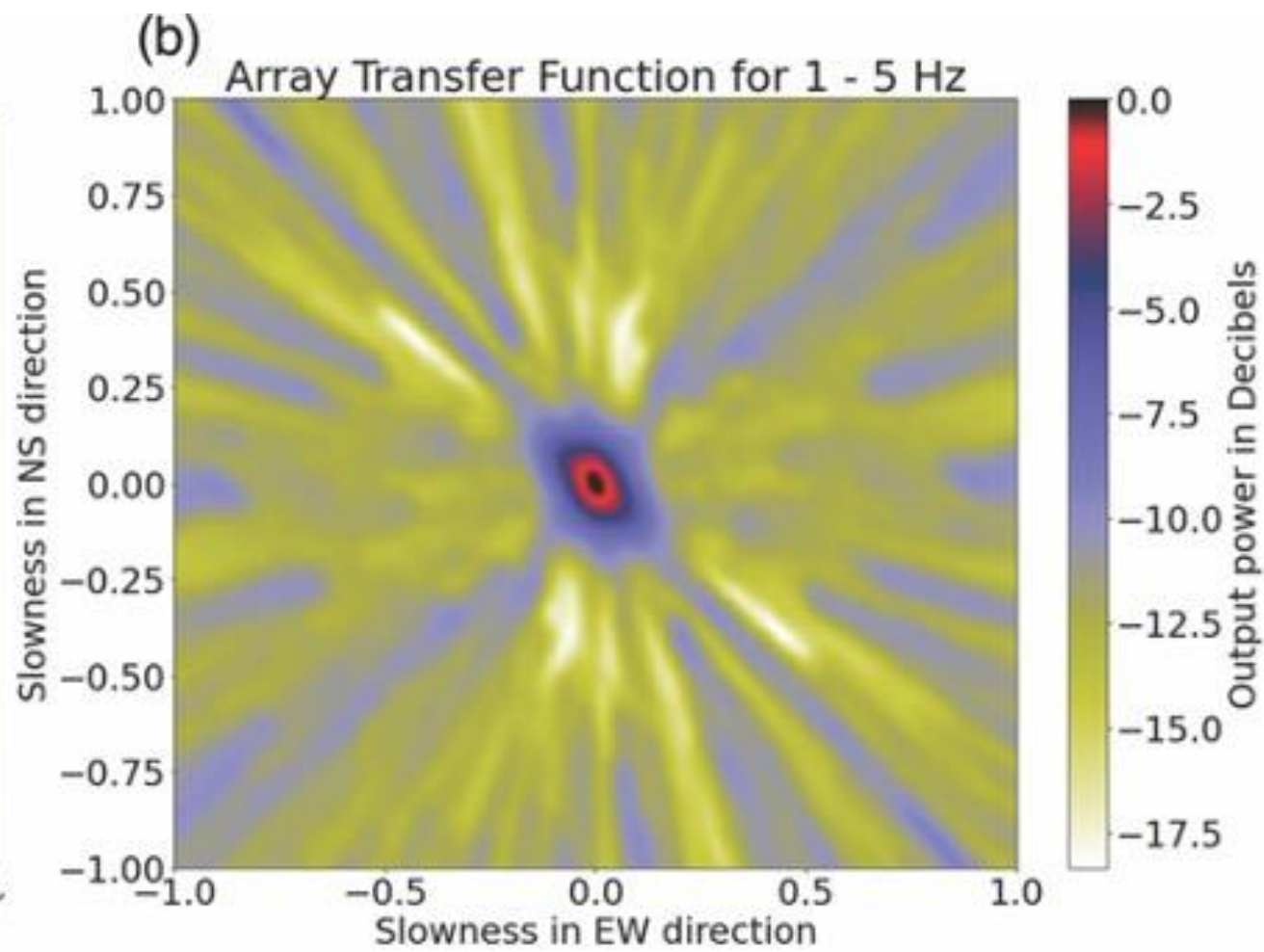
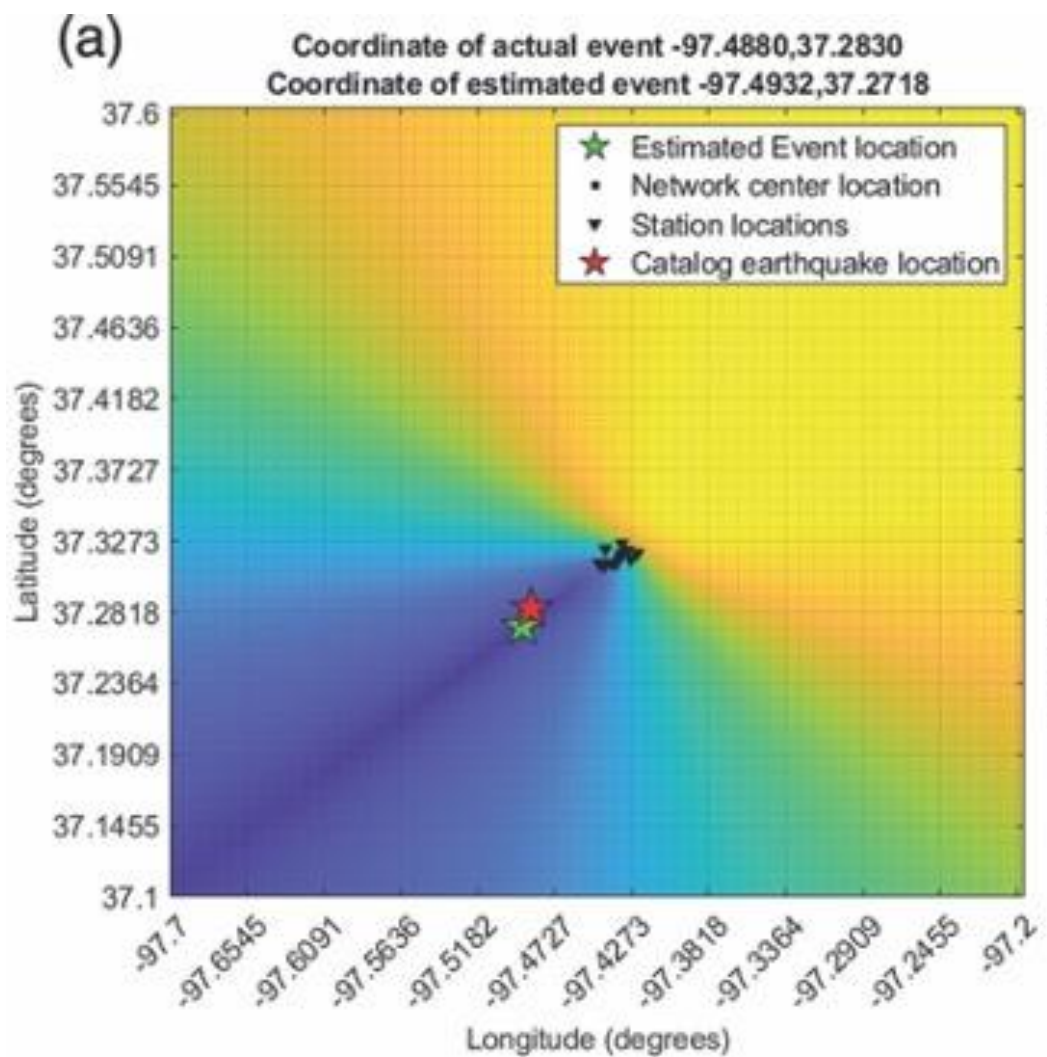


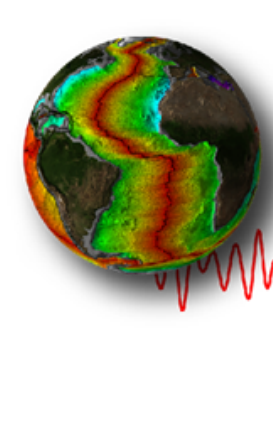
*Ghosh et al., 2009, GRL*



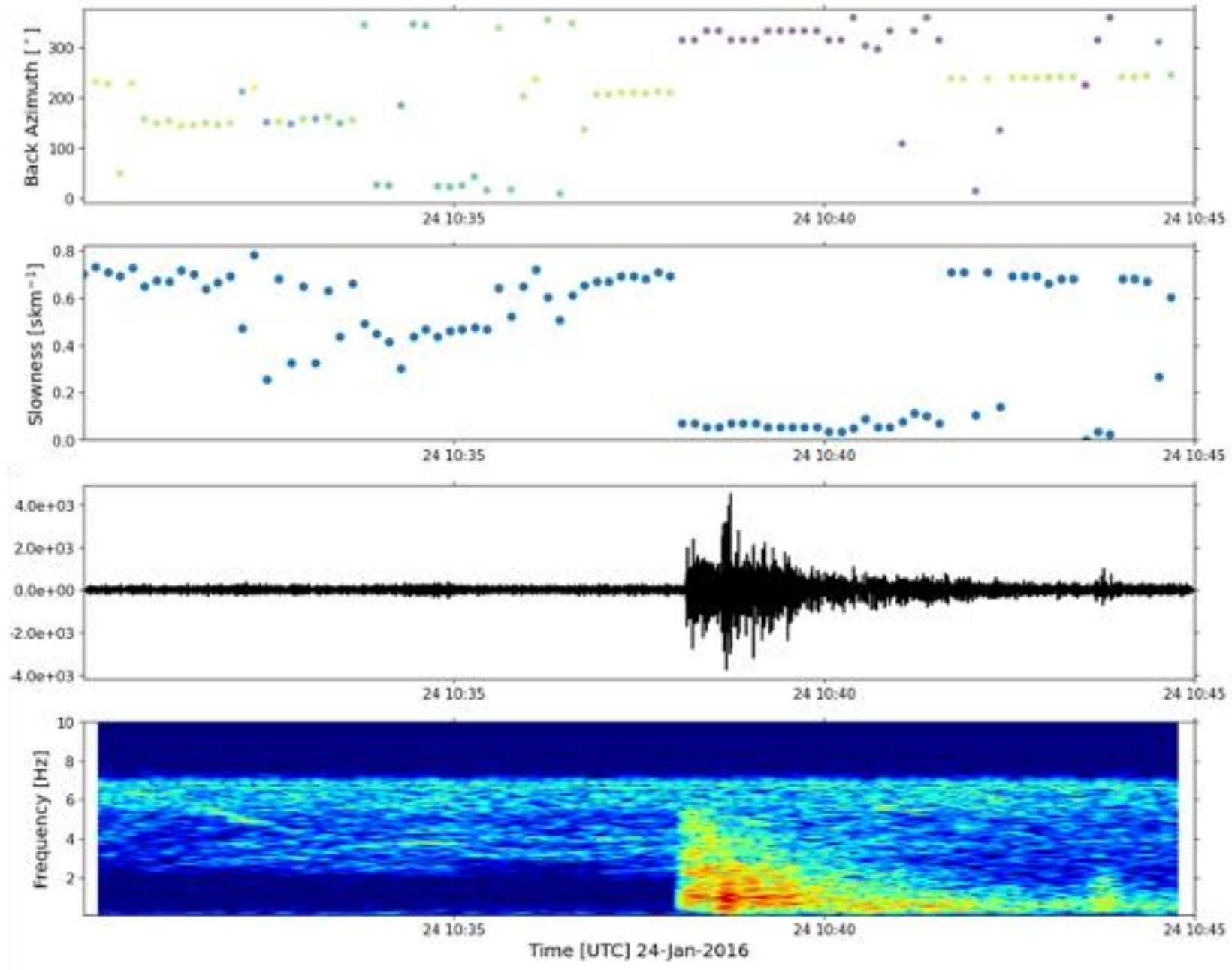


# Array Response and Test

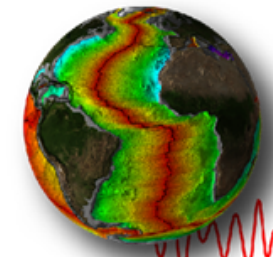




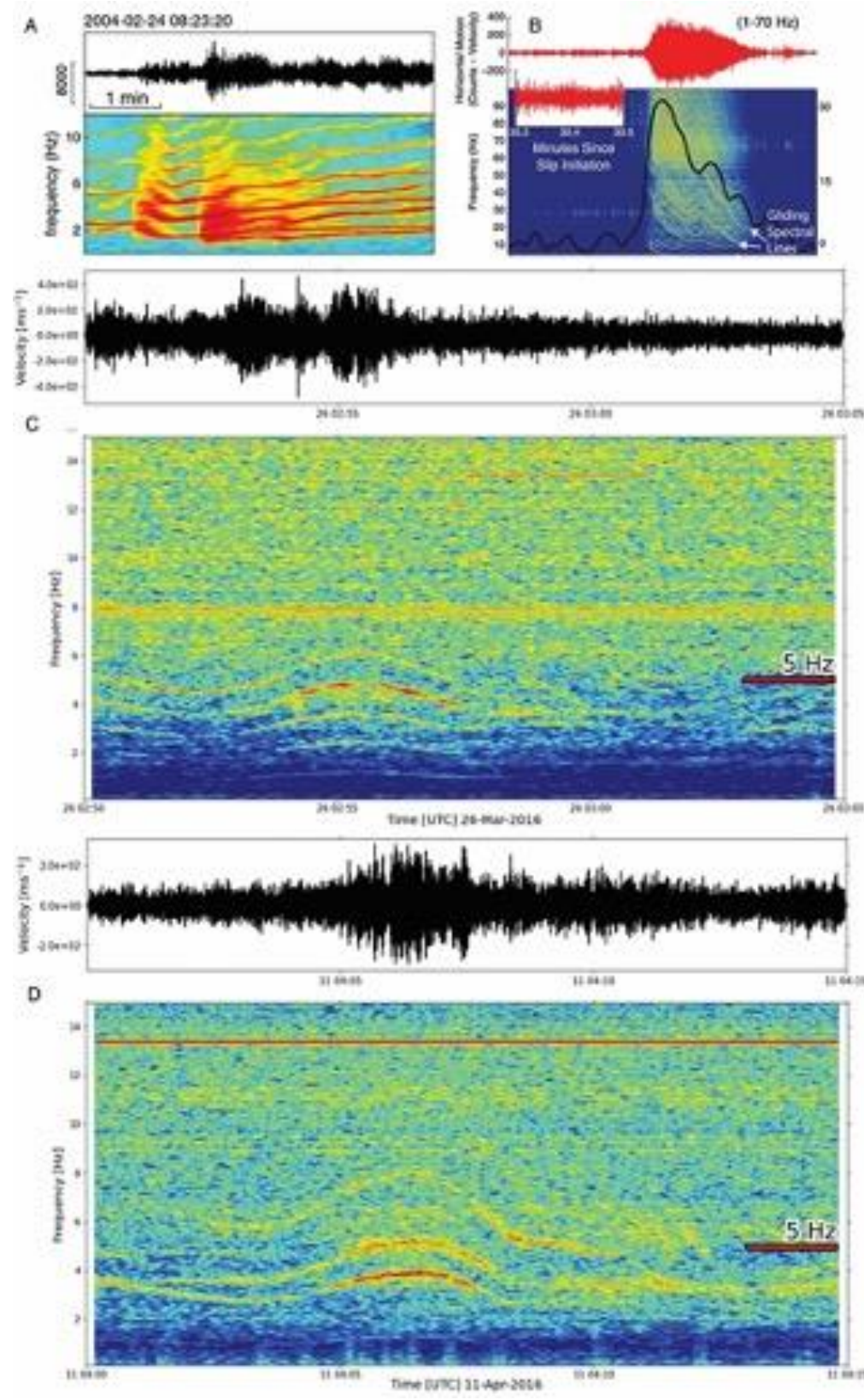
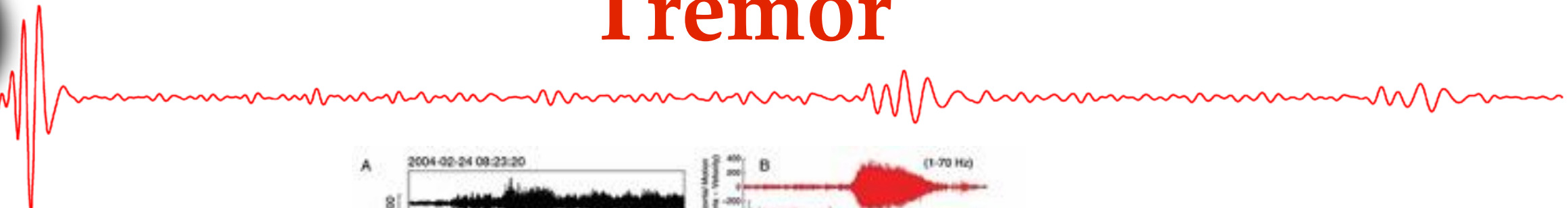
# Low vs High Slowness



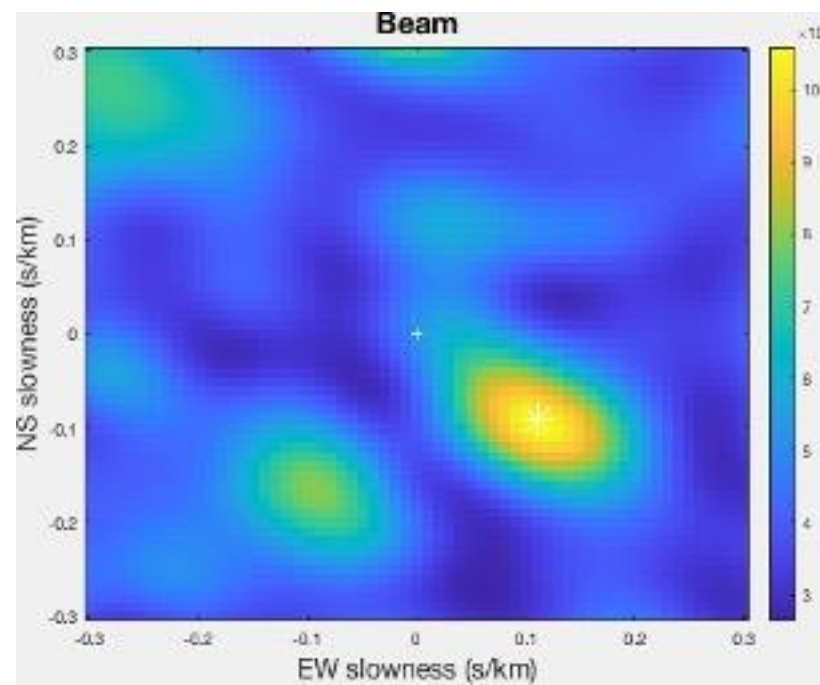
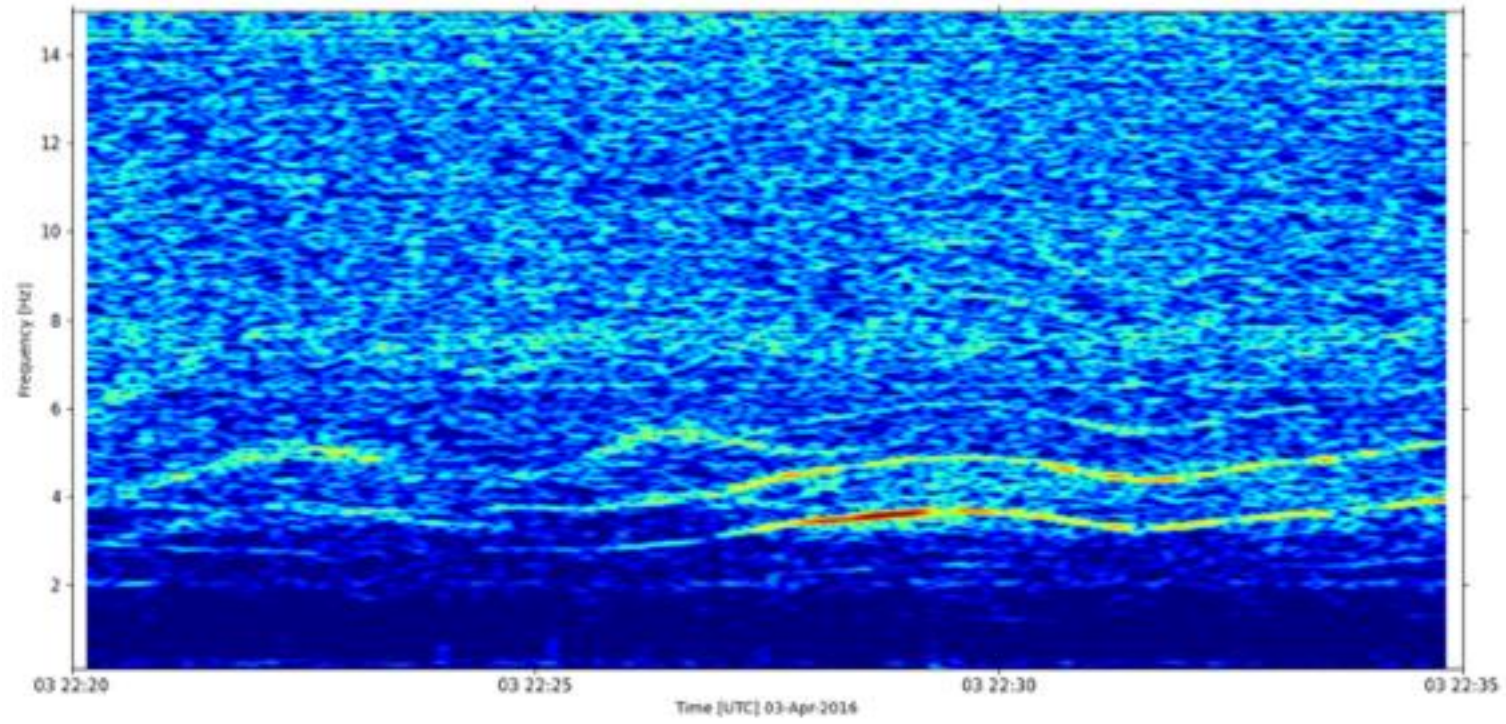
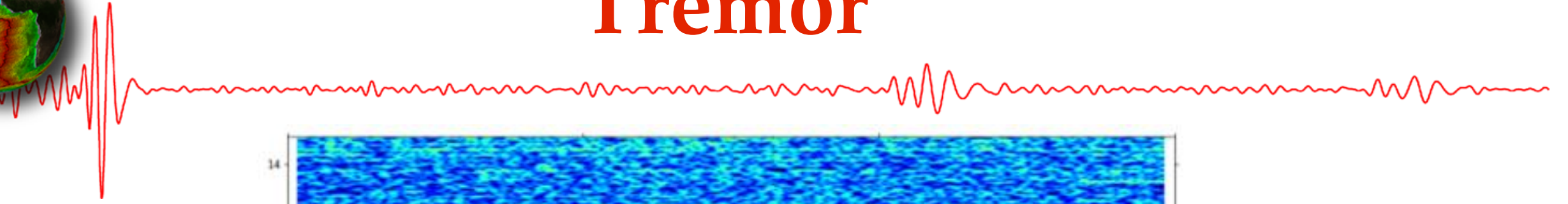
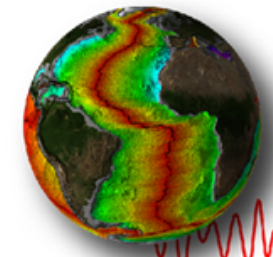




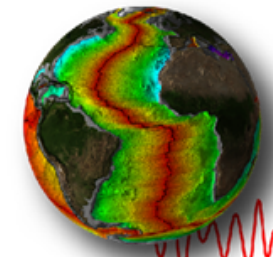
# Tremor



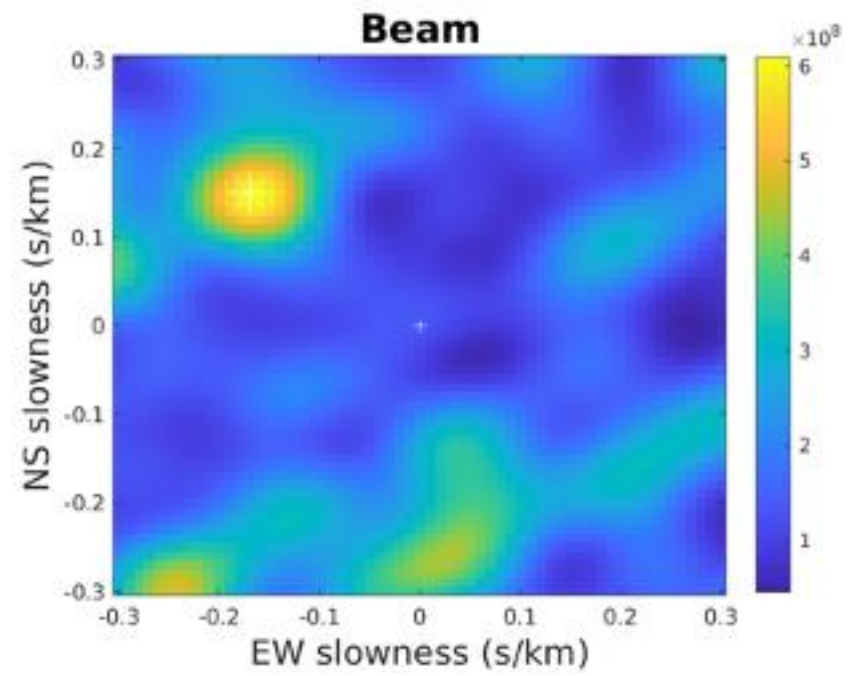
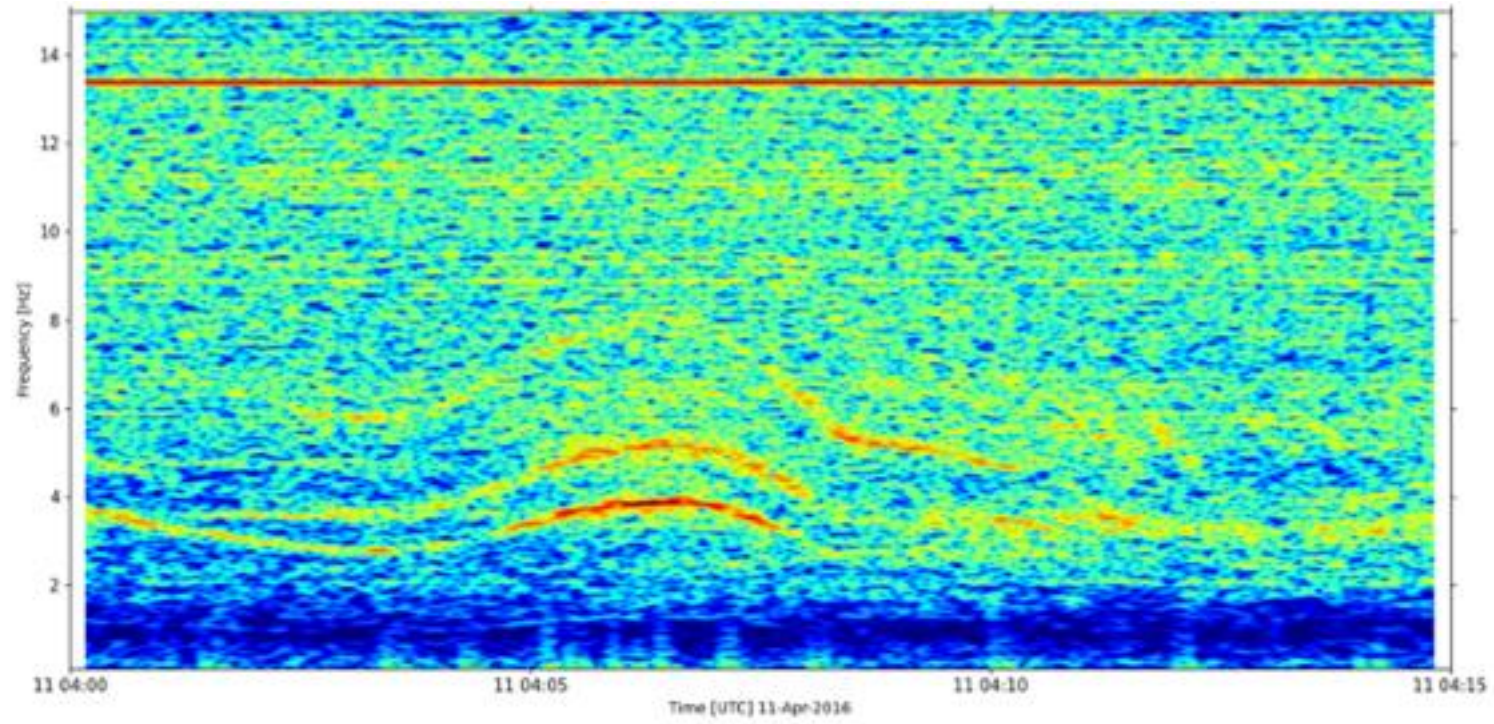
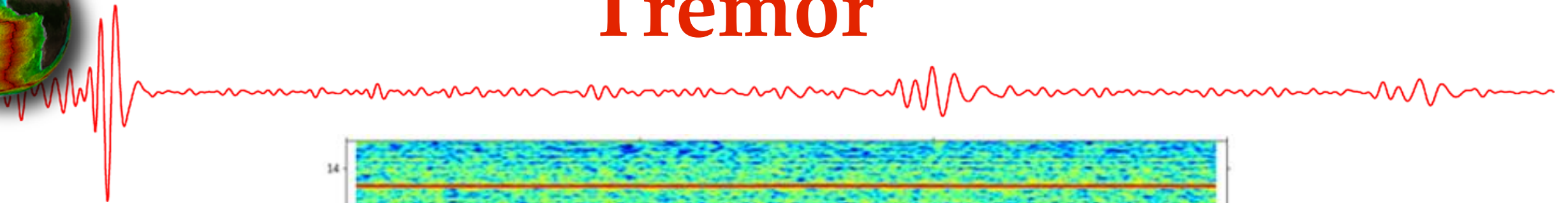
# Tremor



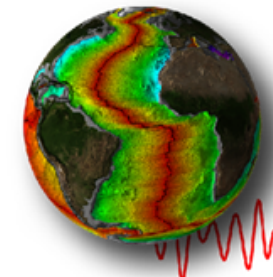




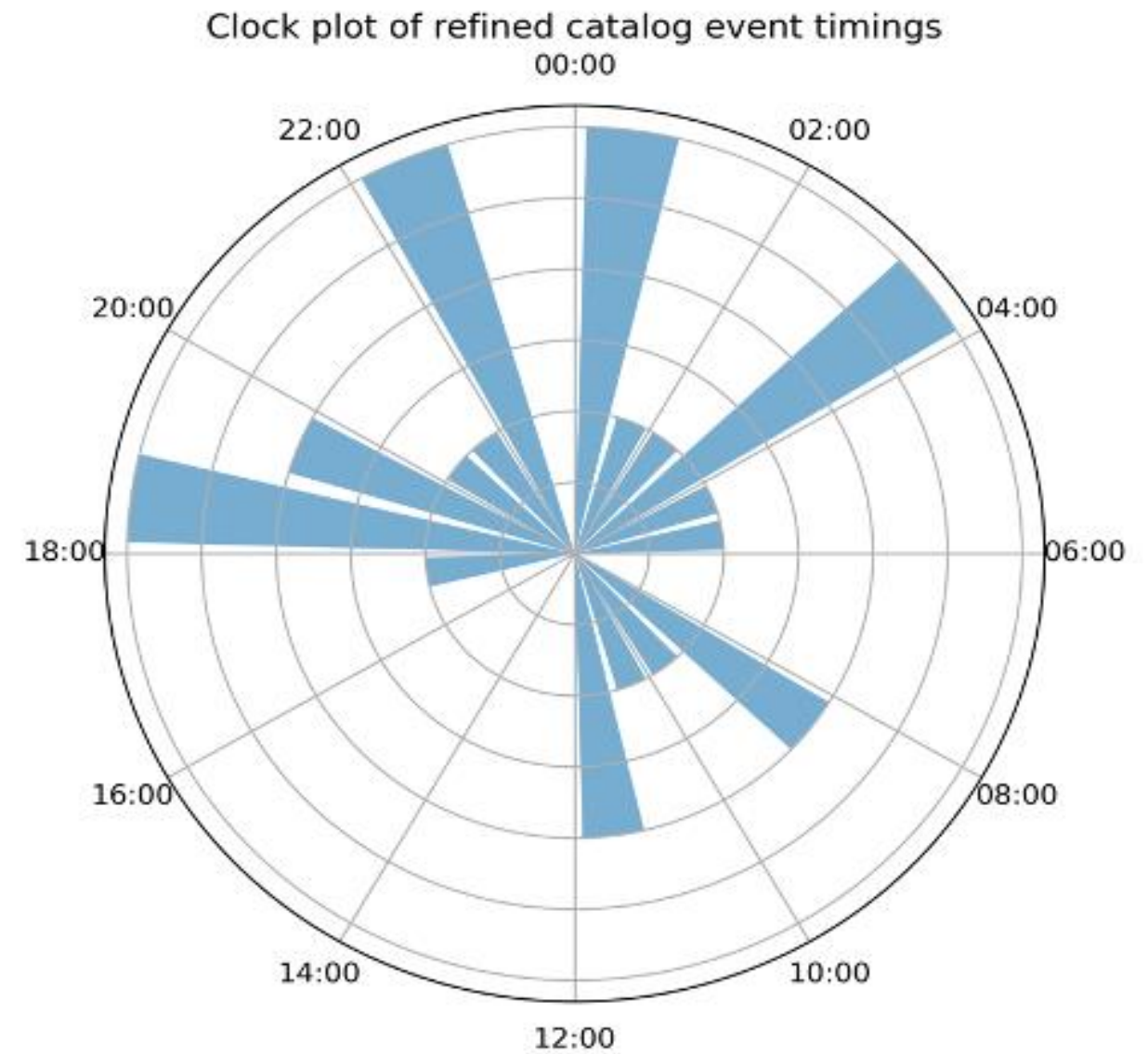
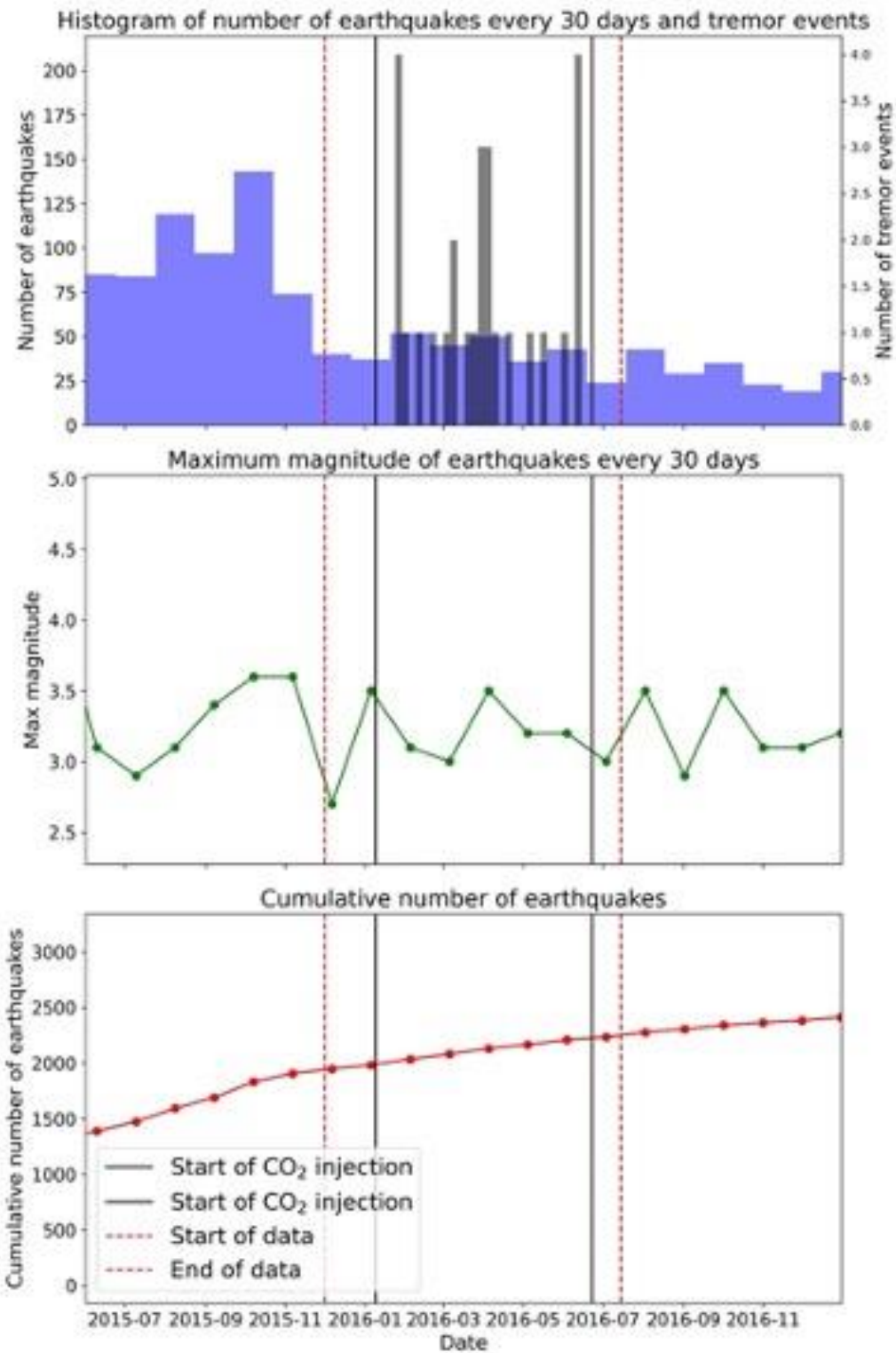
# Tremor

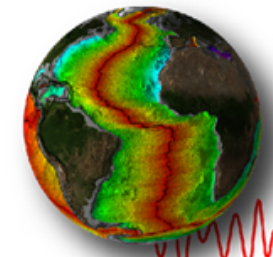




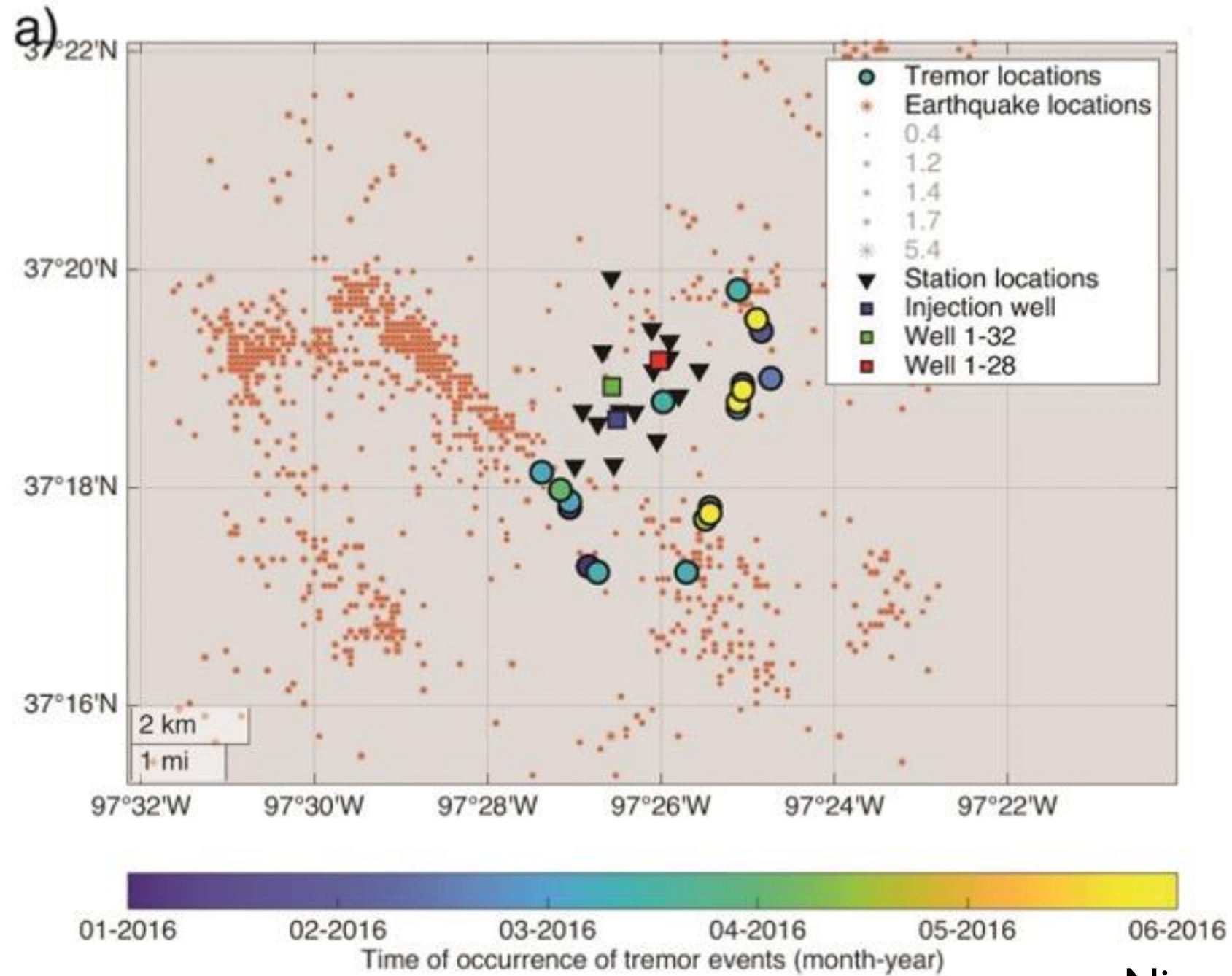


# Tremor Event Timing



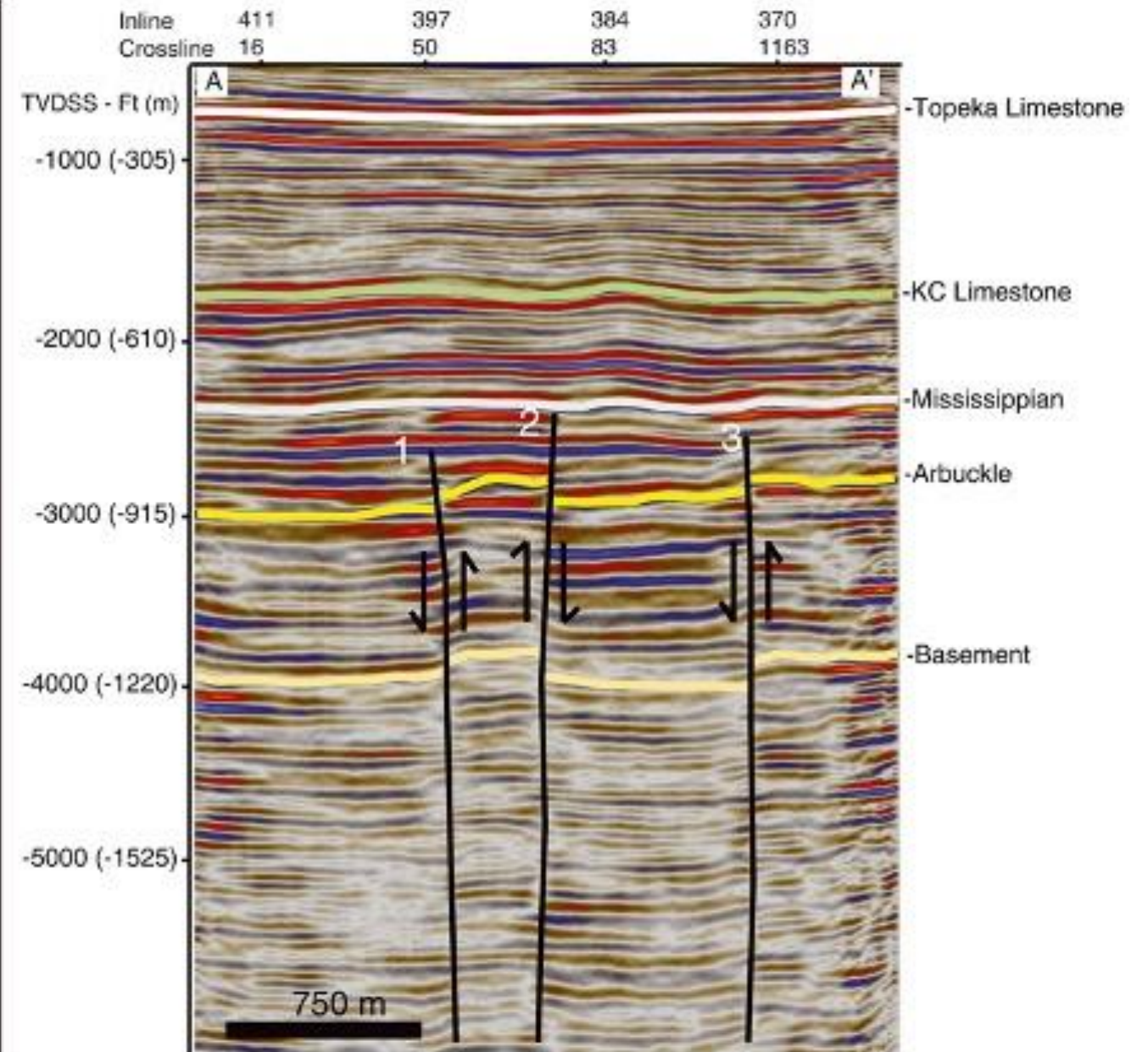
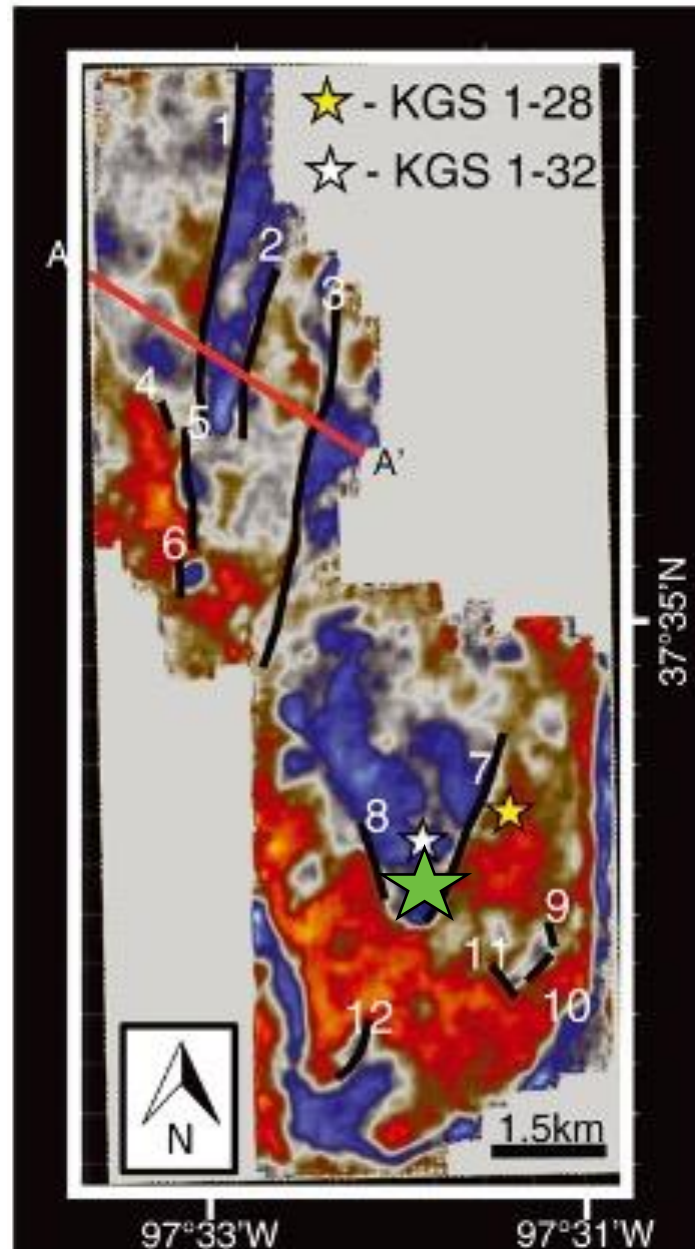


# Tremor location

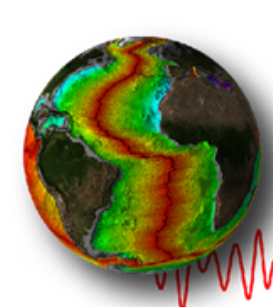




# Faults in the study area

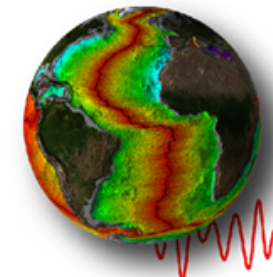






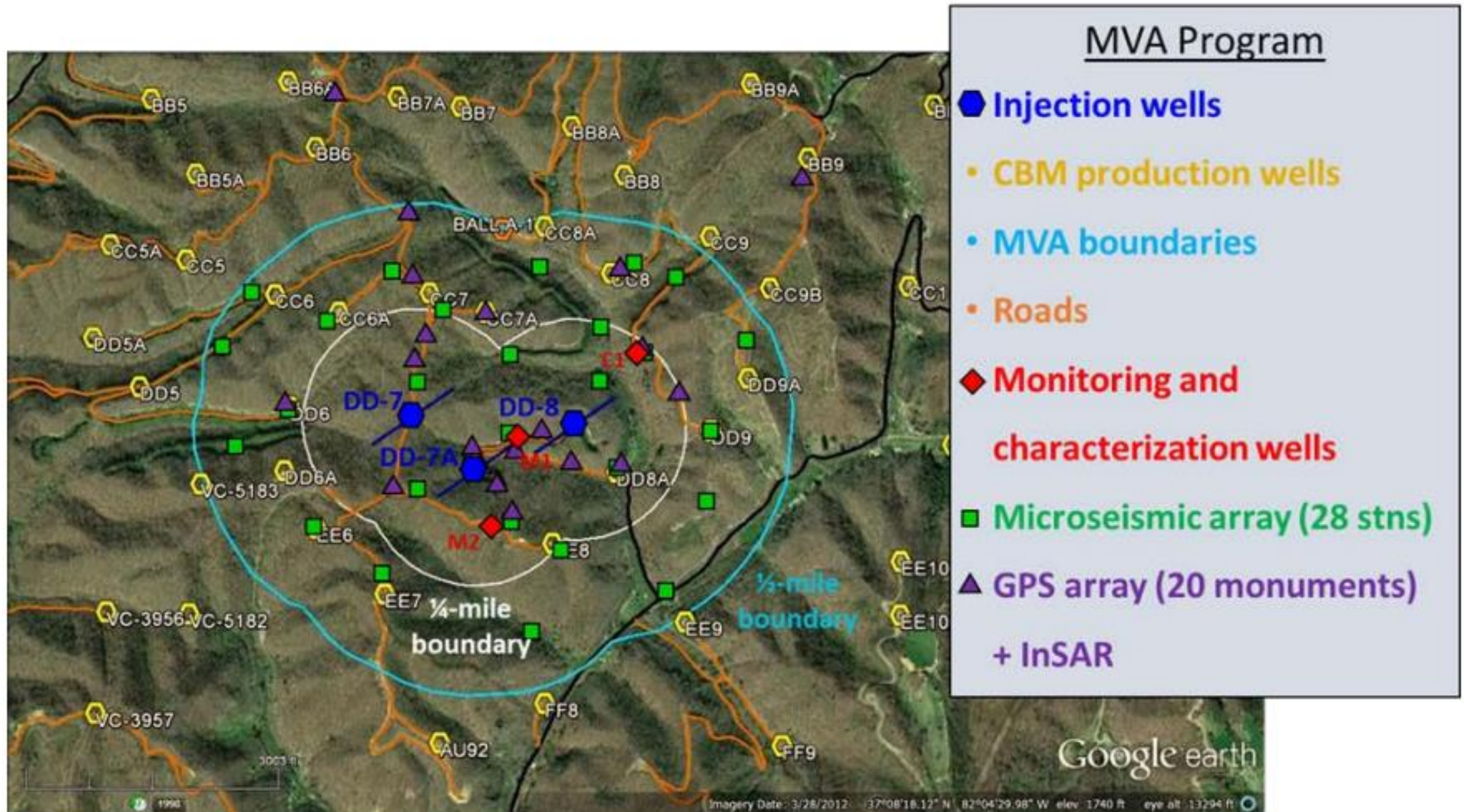
# Evidence in favor of tectonic origin

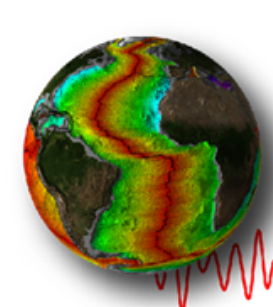
- Low slowness (deep source)
- Unambiguous beam (high resolution)
- Align well with known structures
- No daily or weekly pattern
- Tremor only detected during injection



# Ongoing Research

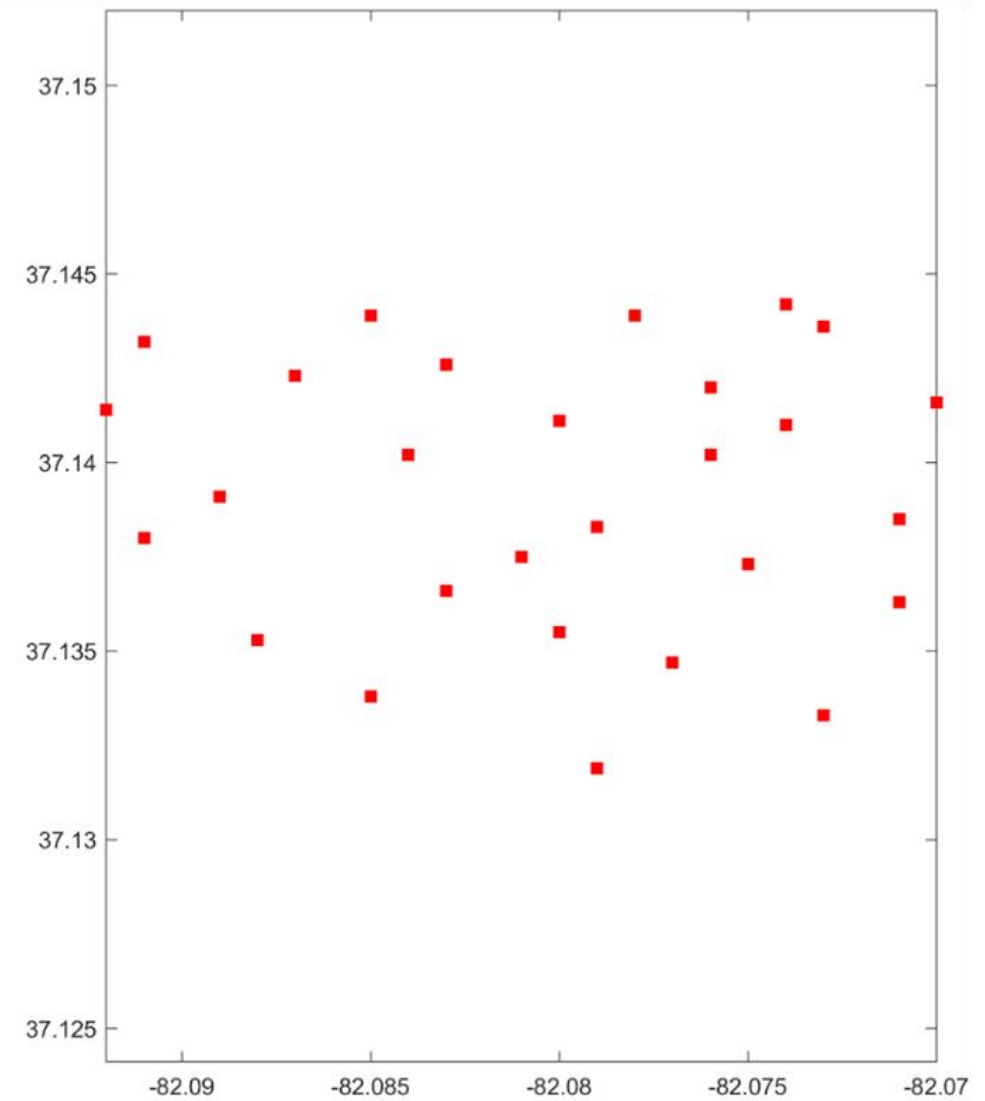
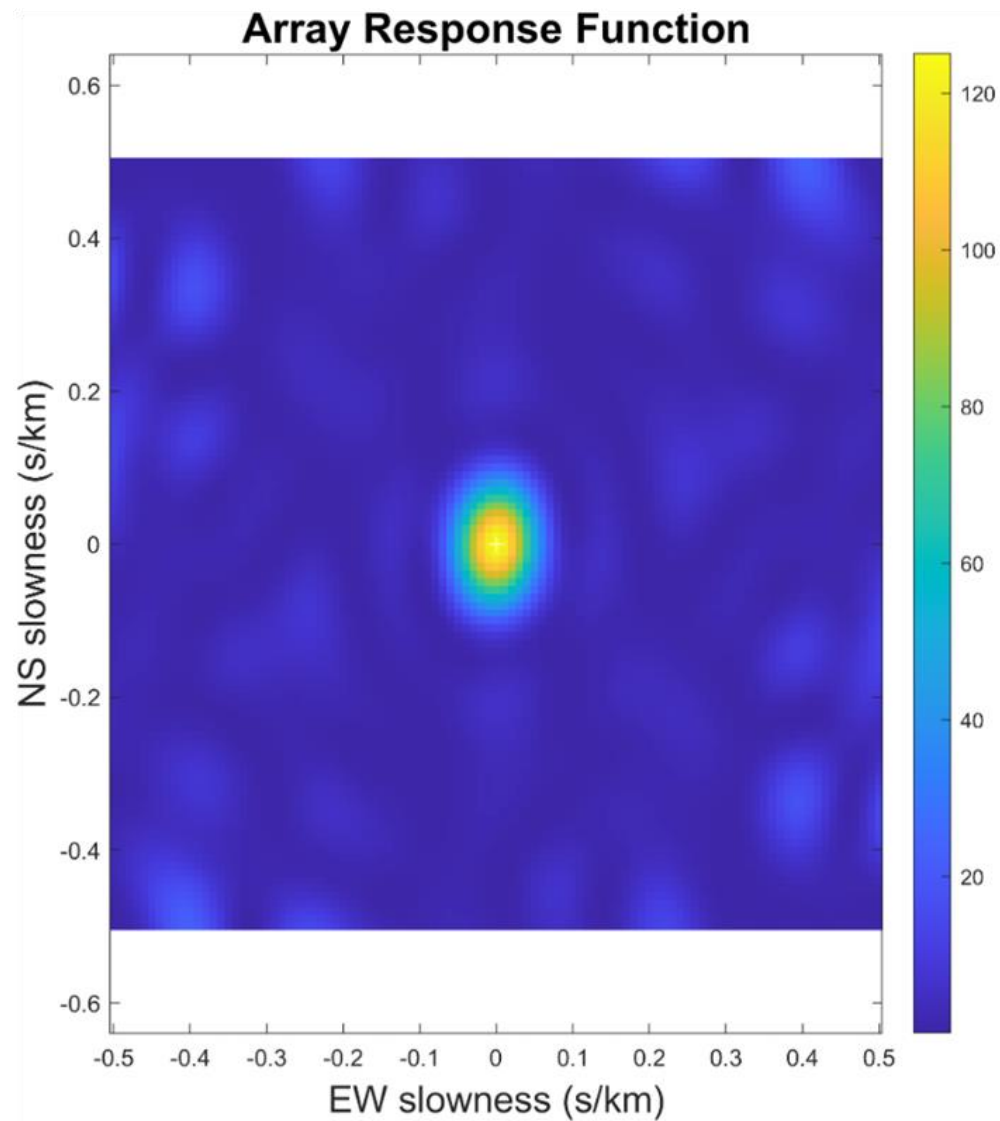
## Seismic array in Buchanan County, VA



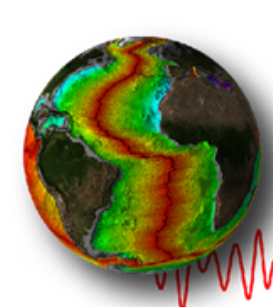


# Array response function at 5 Hz

This seismic array provides excellent resolution



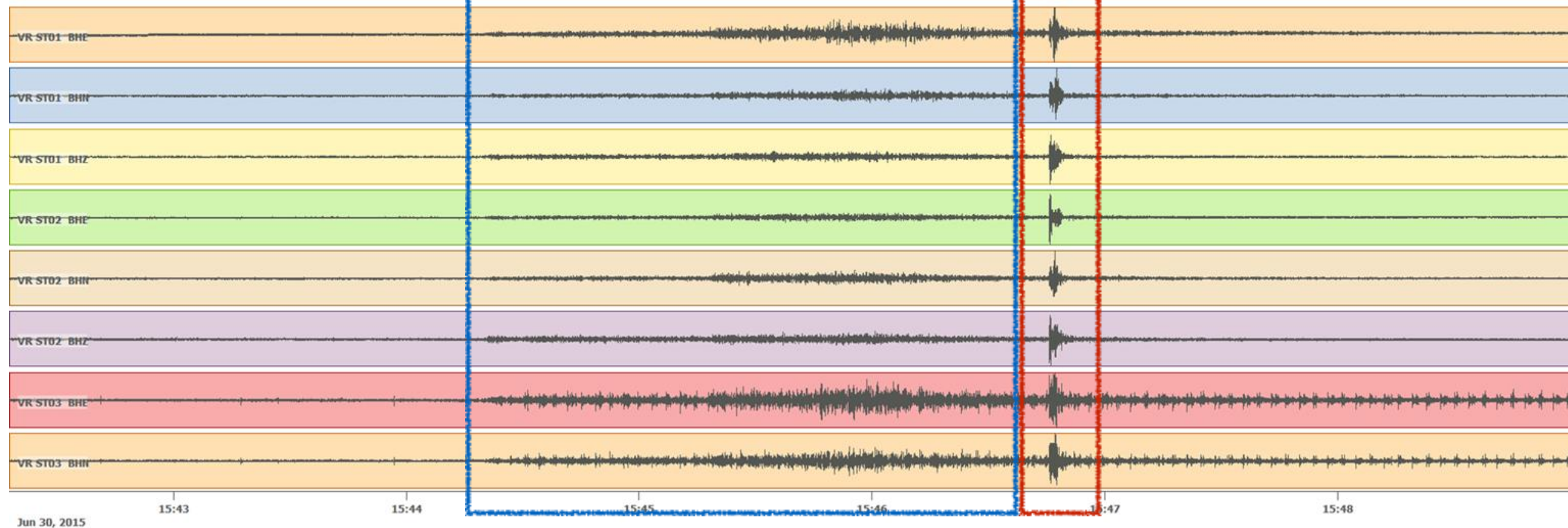


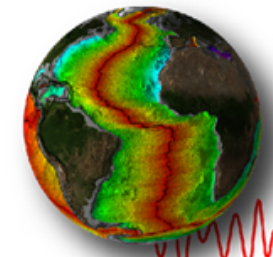


# Dynamically triggered local event?

Regional earthquake  
M3.3 near Burlington,  
Michigan

Dynamically triggered  
event?  
(previously undetected)

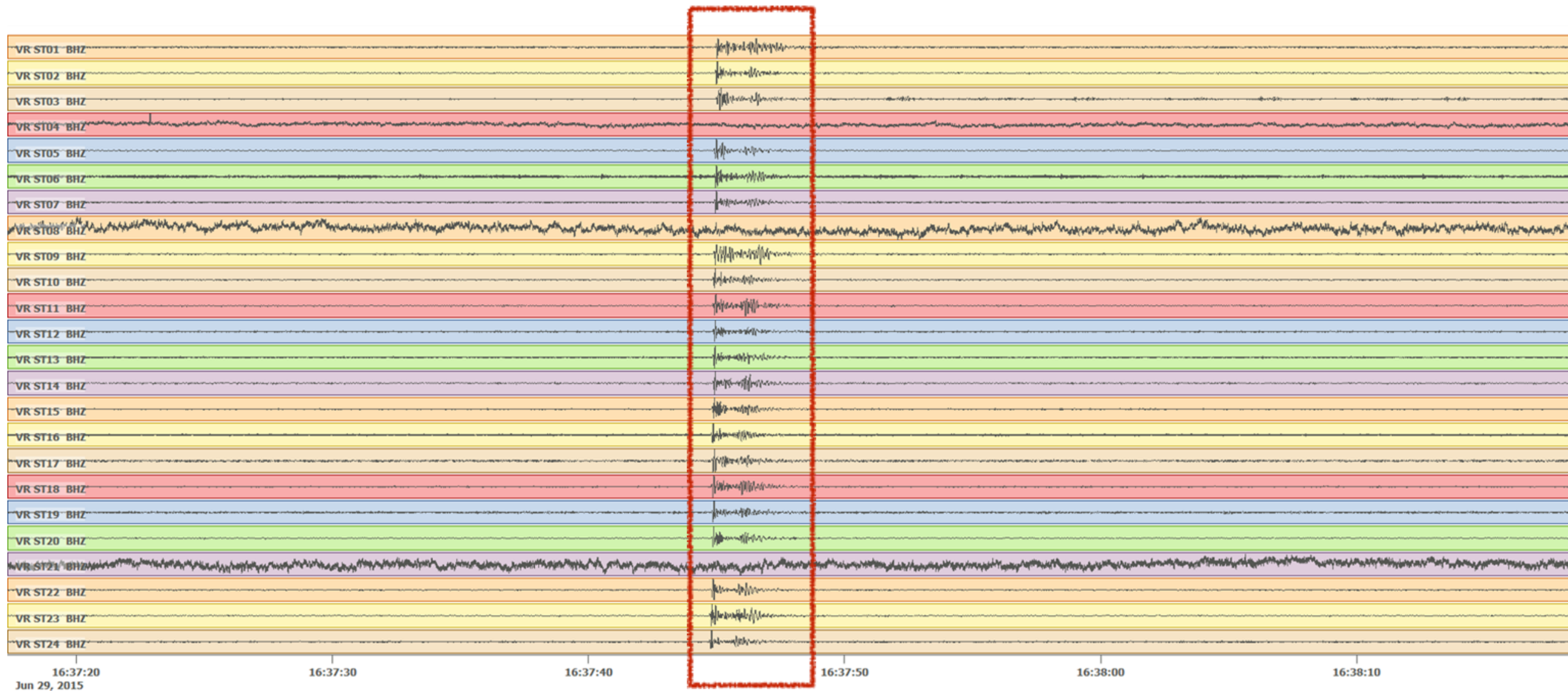




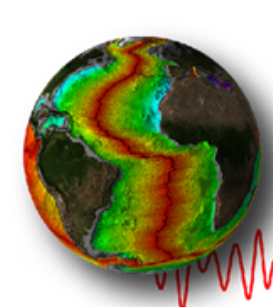
# Plenty of small earthquakes



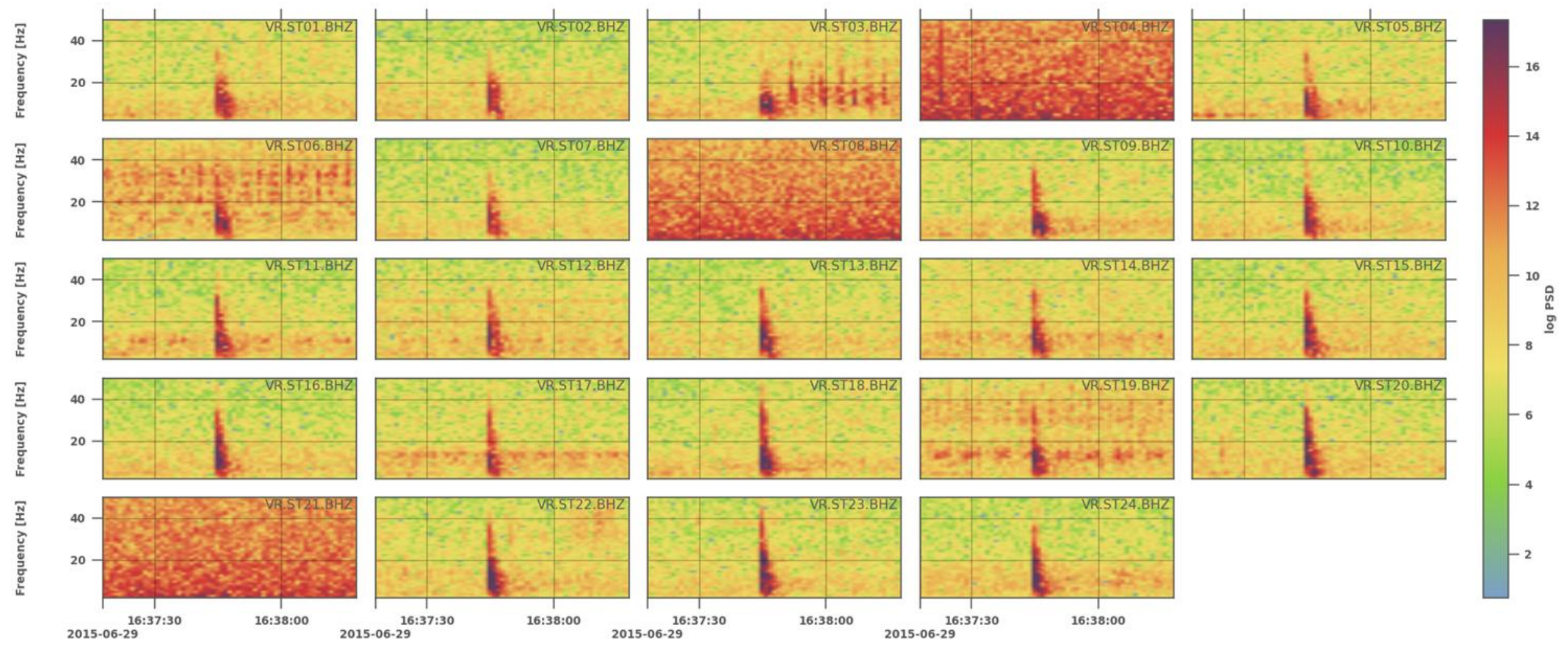
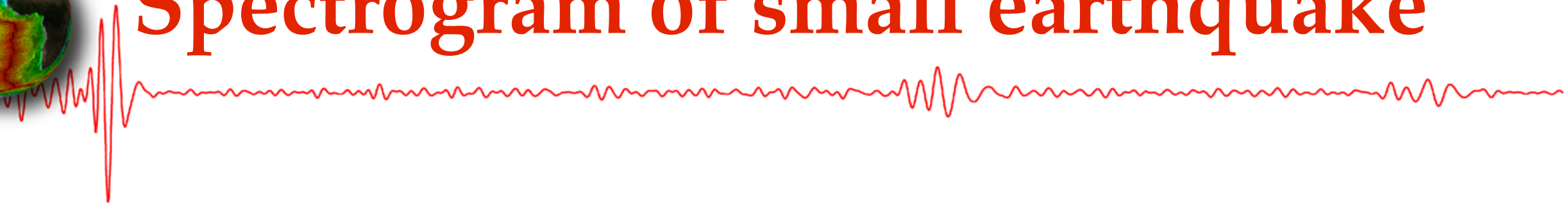
Previously undetected



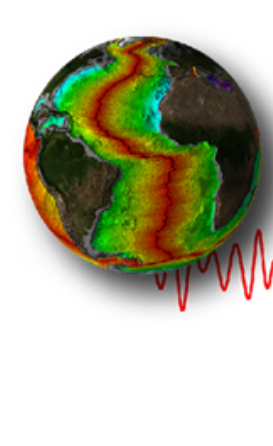




# Spectrogram of small earthquake

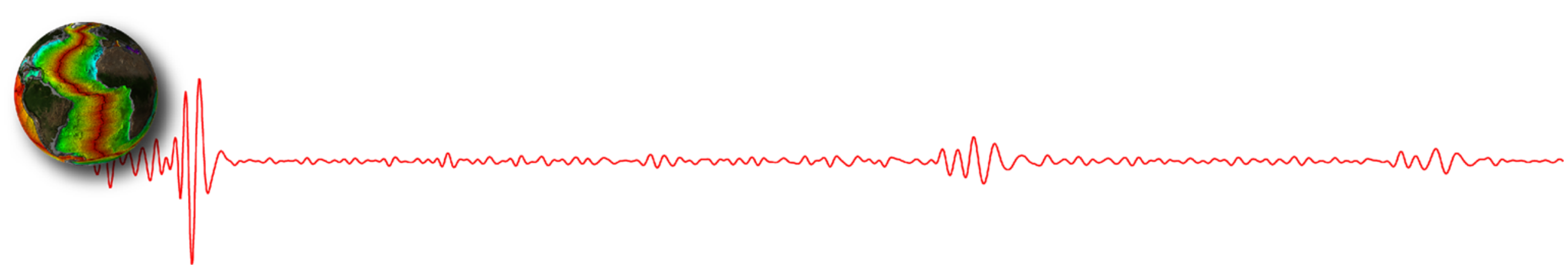






# Future work

- Investigate dynamic earthquake triggering in carbon injection environment
- Detect and locate small earthquakes
- Earthquake activity rate, variations and spatiotemporal distribution
- Systematic search for induced tremor



**Thanks**