SAND2017-8459PE

Characterizing Seismic Scattering in the P-Wave Coda Using A Rotational Seismometer

Jonah Bartrand, University of Idaho

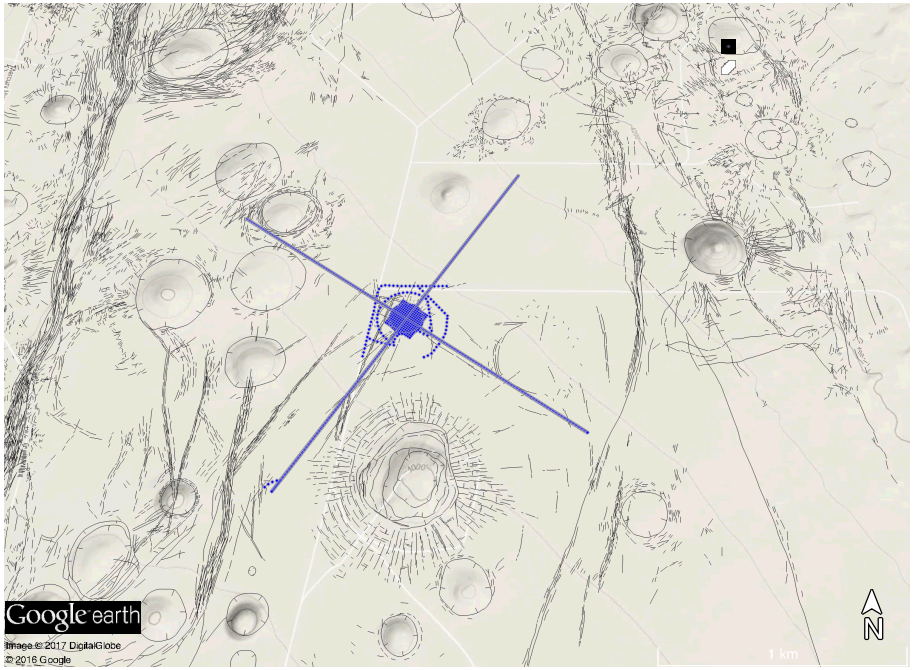
Rio Grande Valley Geophysical Society

10 August 2017

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Frey Chimney Project



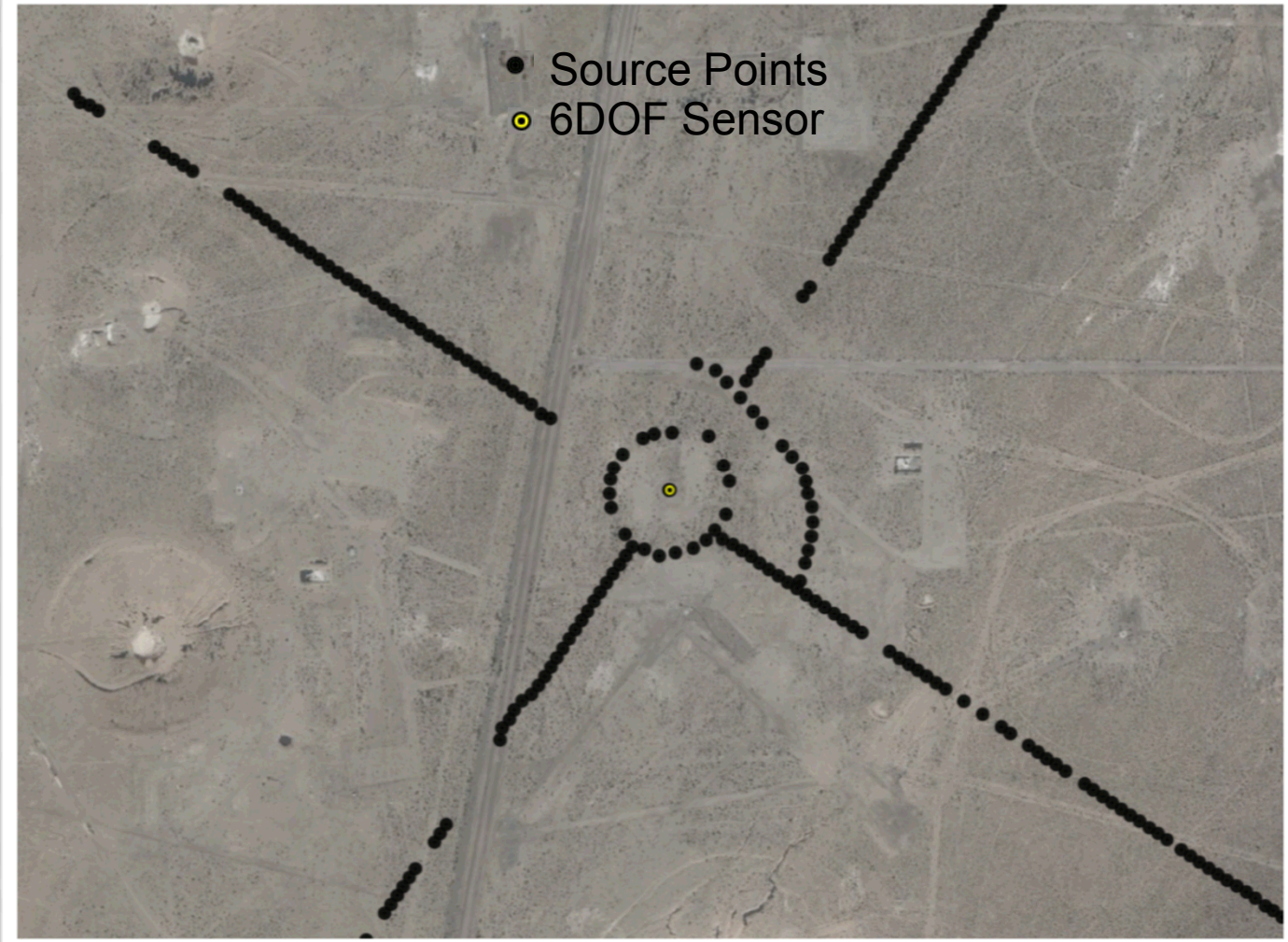
- Active-source seismic experiment over a historical nuclear test (HADDOCK) in Nevada
- HADDOCK did not create a surface collapse
- Goal is to understand resultant geophysical anomaly at depth

Sources	Seismic Hammer™ and AWD
Receivers	1,000 2-Hz 3-C geophones
Recorders	1,000 iSeis Sigma
Source Points	286
Receiver Spacing	5 meters
Source Spacing	15 meters

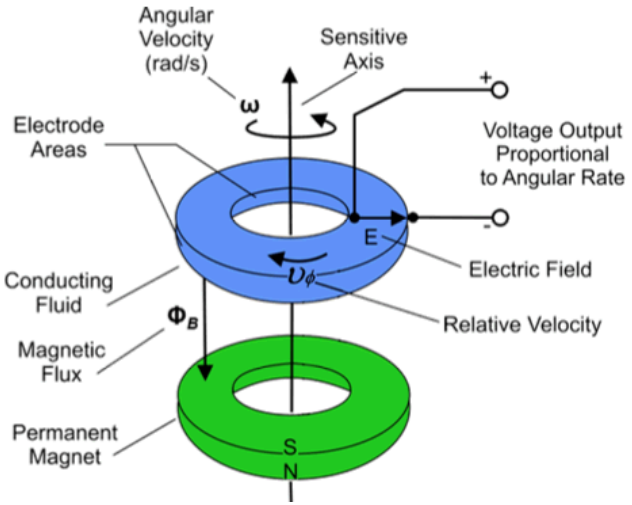
The Seismic Hammer™

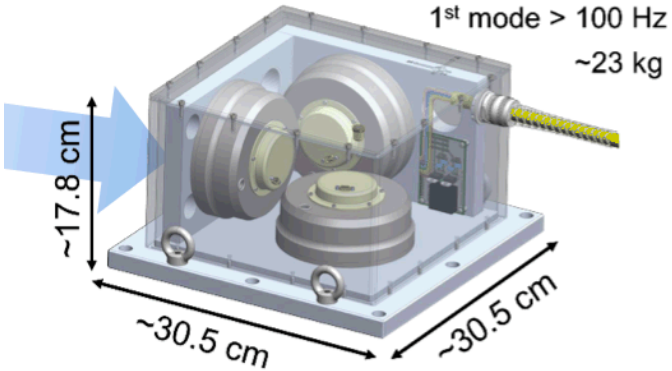
- 13,000 kg weight-drop seismic source
- Weight lifted to 1.5 m and dropped under gravity
- Consistent 191,000 Joules of potential energy per hit.

Data Collect Physical Setup

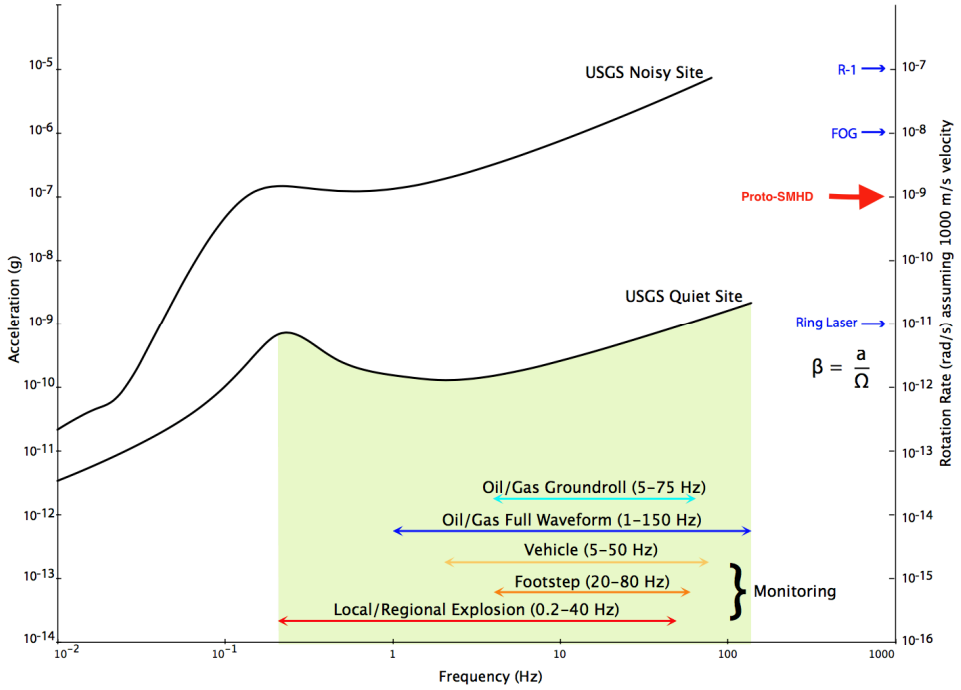


ATA Proto-SMHD Rotational Sensor





A conductive fluid acts as a proof mass. Seismic motion rotates a permanent magnet fixed to the sensor case relative to the fluid, creating an electrical signal proportional to angular rate.

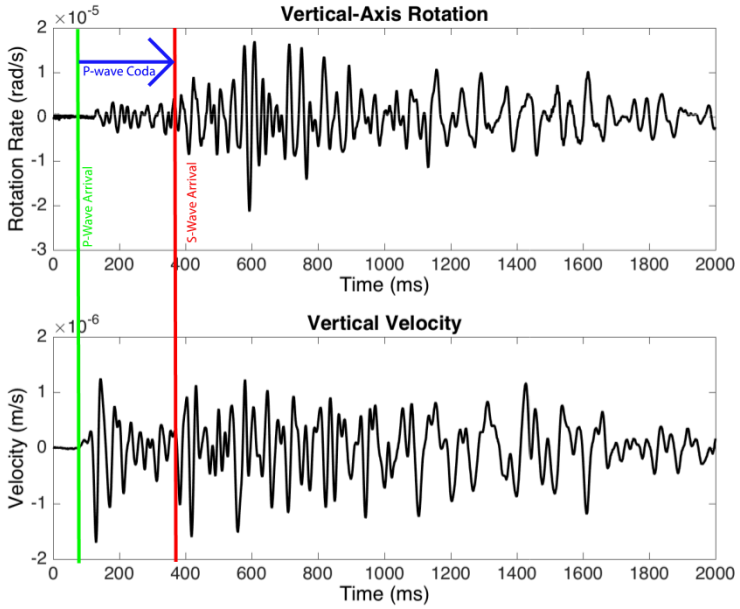


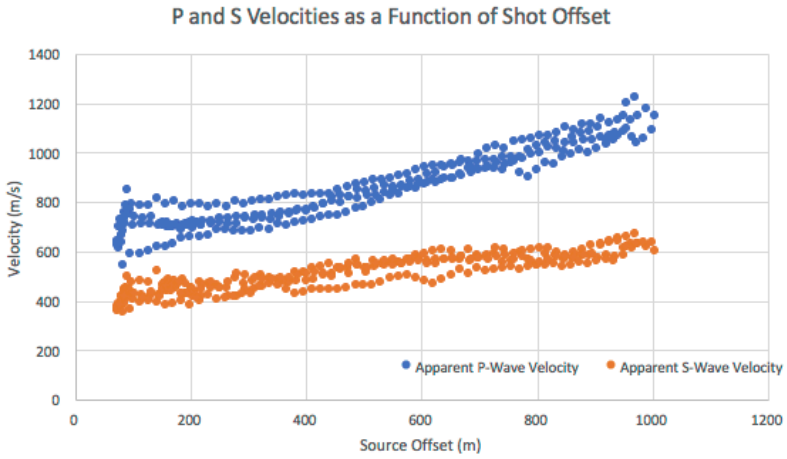
Rotational Signal Scattering Project

Sandia National Laboratories

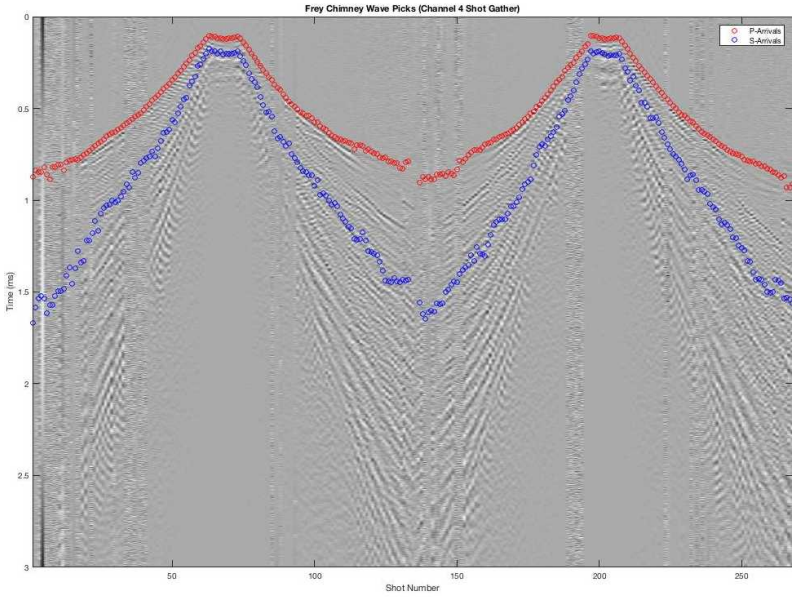
- Theory:
  - Pure compression waves impart no rotational motion
  - Rotational motion in the P-coda should be a result of wave scattering or reflection along the source-receiver path
- Goal:
  - Determine if rotational signals in the P-coda can be used map subsurface scattering
- Verification:
  - Compare with known subsurface geological features at HADDOCK
- Assumptions:
  - All rotational motion in P-coda is a result of wave conversions
  - Single scattering location (to be extended to multiple scatterers in the future)

Wave Arrival Picking





- 283 shots
- Manual picking of both p- and s-wave arrivals



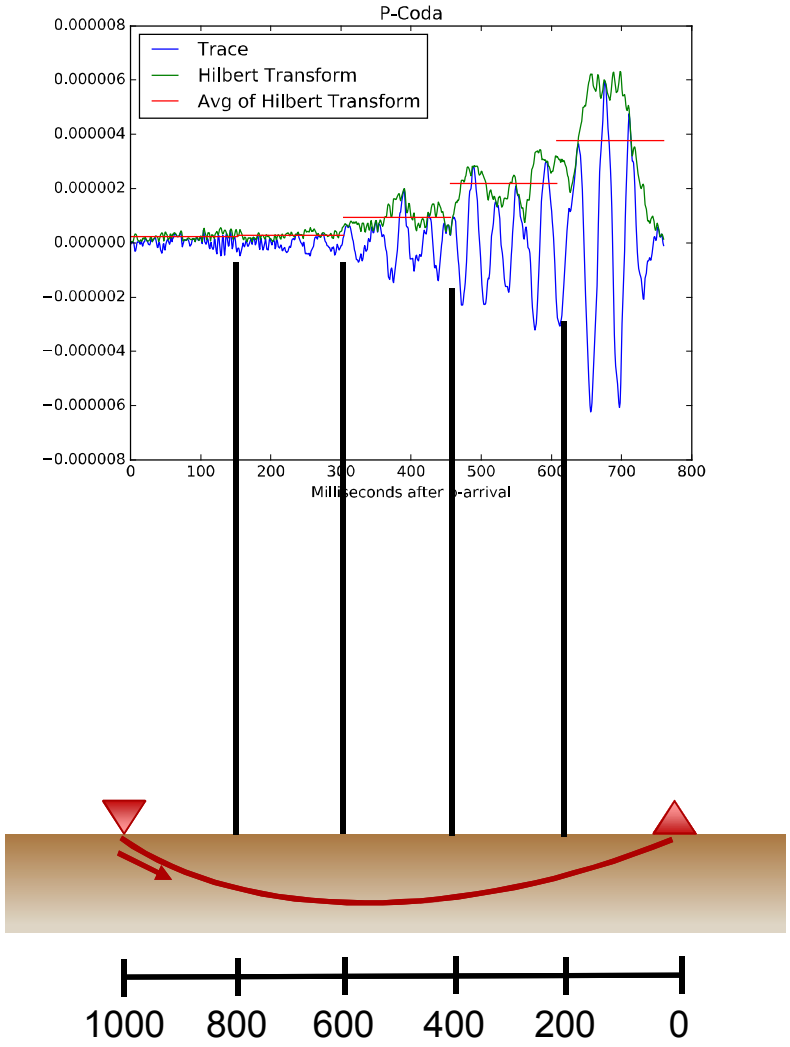
Signal Analysis and Spatial Correlation

1. Divide P-coda into windows
2. Find average continuous amplitude of each window
3. Calculate ratio of rotation and translation values
4. Use velocity-dependent equation to calculate scattering location

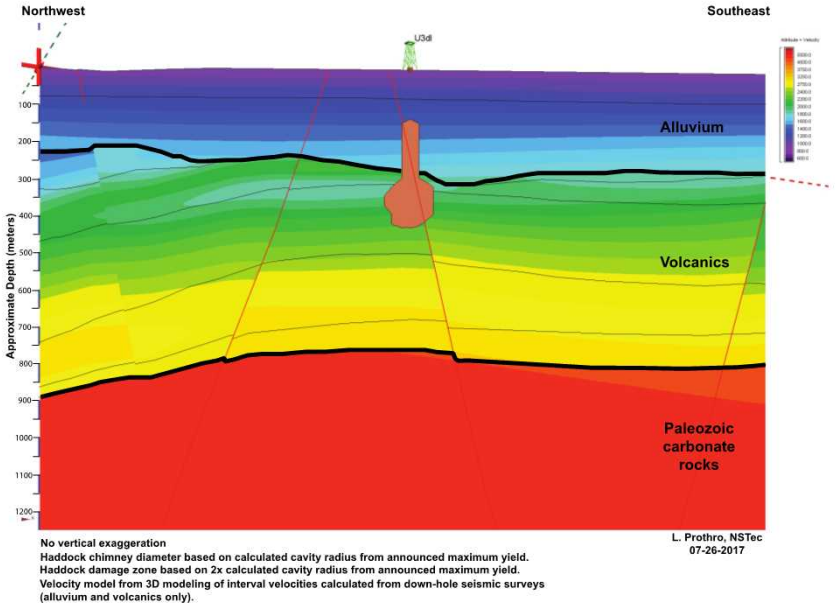
$$\Delta t * \frac{v_p(d) * v_s(d)}{v_p(d) - v_s(d)} = d$$

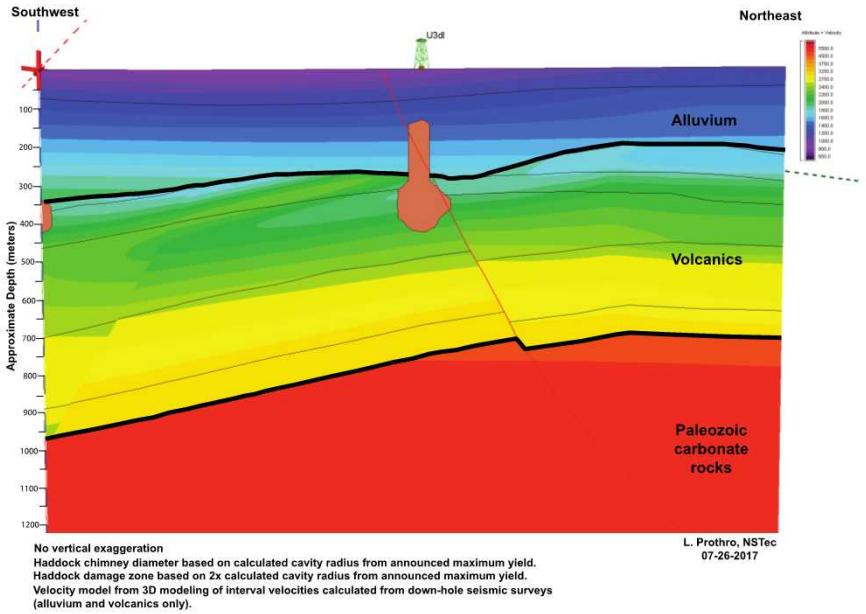
Δt is the time to s-arrival

d is the scattering distance



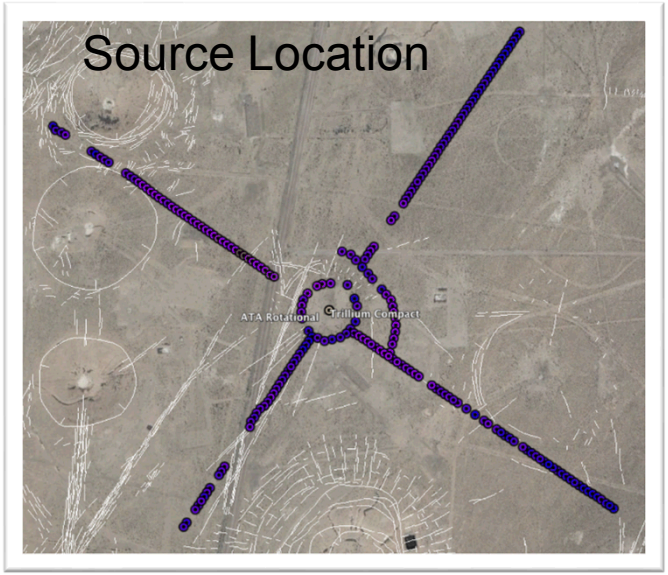
Geographic Cross-Sections





Cross-sections courtesy of Lance Prothro (NSTec)

Scattering Results



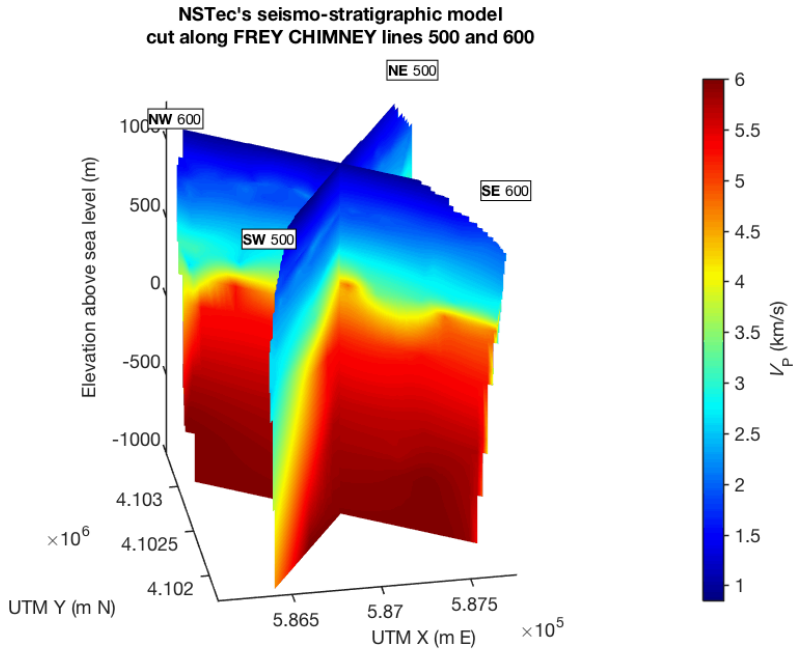
- Northwest arm shows high scattering
- Correlation with fault on x-section

Same image as above, but with scattering intensity projected to assumed scattering point

Discussion of future image (to left)

Further Work

- Define proper ray paths using full survey
- Rotate sensor orthogonal to ray path
- Full tomography to locate scattering point in 3D
- Generalize theory to multiple scattering events



Conclusions

- Summary: We theorize that rotational signal in the P-wave coda is the result of wave scattering
- We tested this with an active source seismic experiment with a consistent source
- Preliminary results show some correlation to mapped geologic features
- Further work is needed to refine theory and extend to 3D