Testing the use of passive seismic methods to detect underground cavities

R. Mellors, E. Matzel, and J. Sweeney

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Overview

Previous work
• Used surface waves from an active source to infer velocity changes.

Question:
• Can we use purely passive seismic with no active source to detect cavity?
  • Seismic interferometry.
  • “resonant seismic” using earthquake signals.

Method:
• Conduct initial 3D models.
• Deploy seismometers around a known underground nuclear explosion site.
• Resources similar to that available for an OSI aftershock deployment.

Example cross-section from surface wave dispersion with active source
Modeling

- Use 3D modeling code to generate synthetic Green’s function.
- Evaluate sensitivity to cavity and velocity model characteristics.

- 3D finite difference code (full waveform)
- 2.0 x 2.0 x 2.0 km block; 5m grid size.
- Use parameters (depth, approximate size and geometry) from existing UNE site.
- Assume filled cavity with lower density material and surrounded by zone of fractures.
- Velocity model based on previous geologic and geophysical studies in similar setting (volcanic tuff and rhyolites).
3D modeling example

Seismic amplitudes
Vertical cross-section

Synthetics
Black = with cavity
Red = no cavity
Seismic interferometry

- Compute cross-correlations of noise; stack
- Yields Green’s functions of the subsurface for each pair of stations
- 1D velocity structure for each path can be estimated from the Green’s functions using either:
  - Estimate dispersion and invert
  - Full waveform inversion of the Green’s function
- Interpolate all 1D paths to generate 3D structure
- Look for anomaly related to structure; compare waveforms with synthetics
Interferometry processing

Processing
1) Collect continuous data
2) Process in one hour segments
3) Apply signbit normalization to eliminate high-amplitude artifacts
4) cross-correlate segments
5) Stack cross-correlations

processing
• 8 broadband instruments (Trillium Compacts 120)
• 3 deployments with different configurations (46 days, 86 days, and 90 days)
• Centered on same location but different scale and geometry
Full Coverage

- Site locations constrained by topography
- Few days of data yield sufficient signal-to-noise at short distances
- Processing in progress

Example showing little variation in SNR with increasing stacking at an inter-station distance of 200 m.
Data example

Green’s functions for each pair with respect to S8
Site effects from cavities?

• Do cavities create observable signatures at sensors above cavity?
• “resonant seismology”
• Expect to see at high frequencies
• Data:
  – Use array crossing location of cavity
  – Examine waveforms of teleseismic P waves
Example of teleseismic wave

M 6.6 160 km deep Jujuy, Argentina 75 degrees

unfiltered

band pass 1-10 Hz

seconds

25 30 35 40 45 50

D3S1
D3S2
D3S3
D3S4
D3S5
D3S6
D3S8

D3S1
D3S2
D3S3
D3S4
D3S5
D3S6
D3S8

200 m

D3S8
Conclusions

• Deployments as short as a few days can yield useful results for seismic interferometry.

• Re-arranging configurations can yield dense ray coverage.

• Use of passive methods effective and low-cost.

• No clear evidence of site response above cavities.