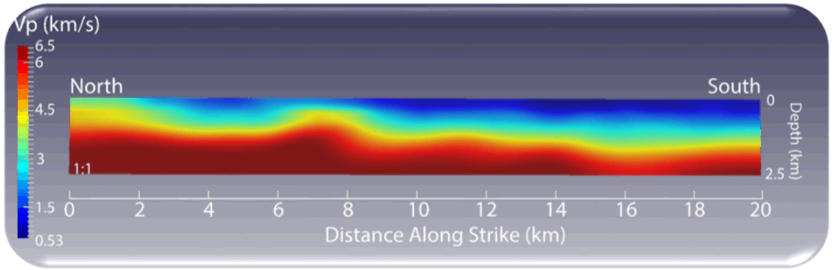
SAND2017-12964PE



The Seismic Hammer™ in Yucca Flat, NV

Robert E. Abbott
Distinguished Member of Technical Staff
Geophysics Department

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

Disclaimer

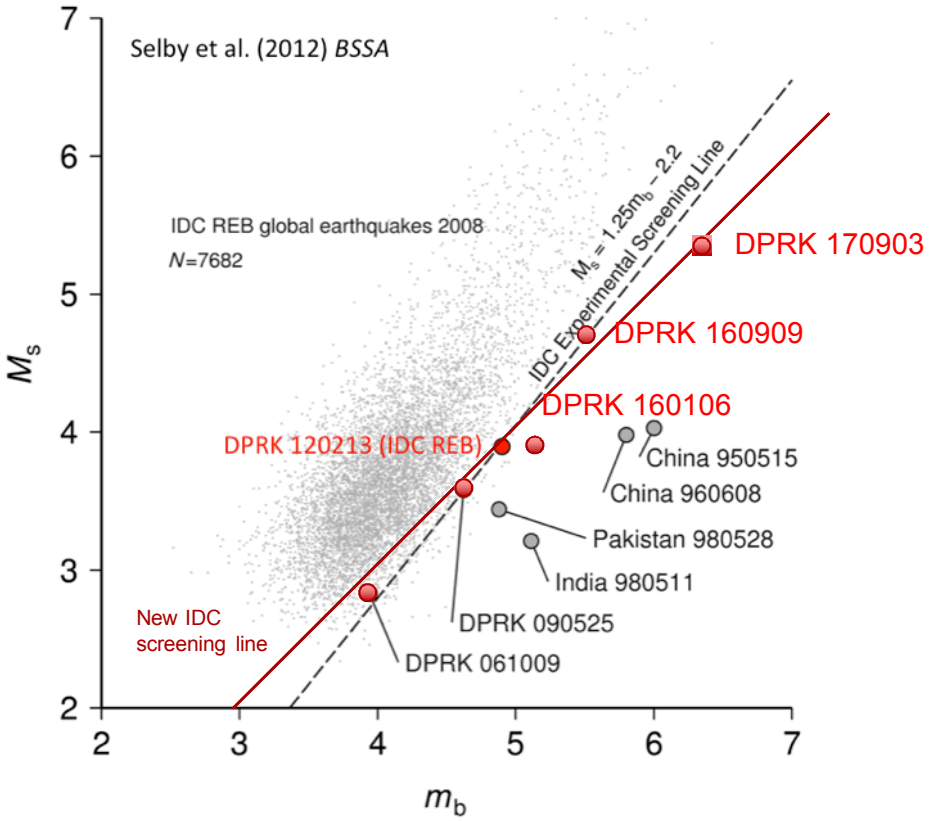
Sandia National Labs does not endorse products or services

Seismic Hammer™: The Movie

Source Physics Experiment Goals

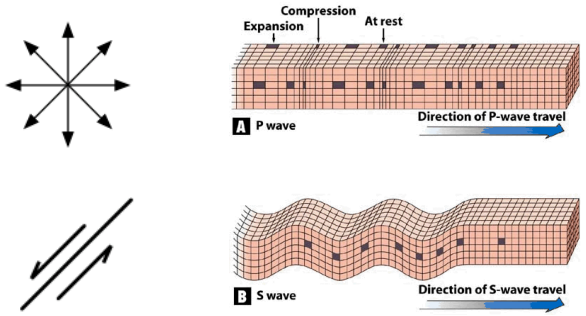
- SPE systematically examines the phenomena in the source region of explosions
  - The causes of shear-wave creation is of particular interest
- Conduct a well-instrumented series of explosions at the Nevada National Security Site (formerly NTS)
- Use seismic and other recordings as groundtruth for more physics-based models (as opposed to current empirical models)

Why Shear Waves?



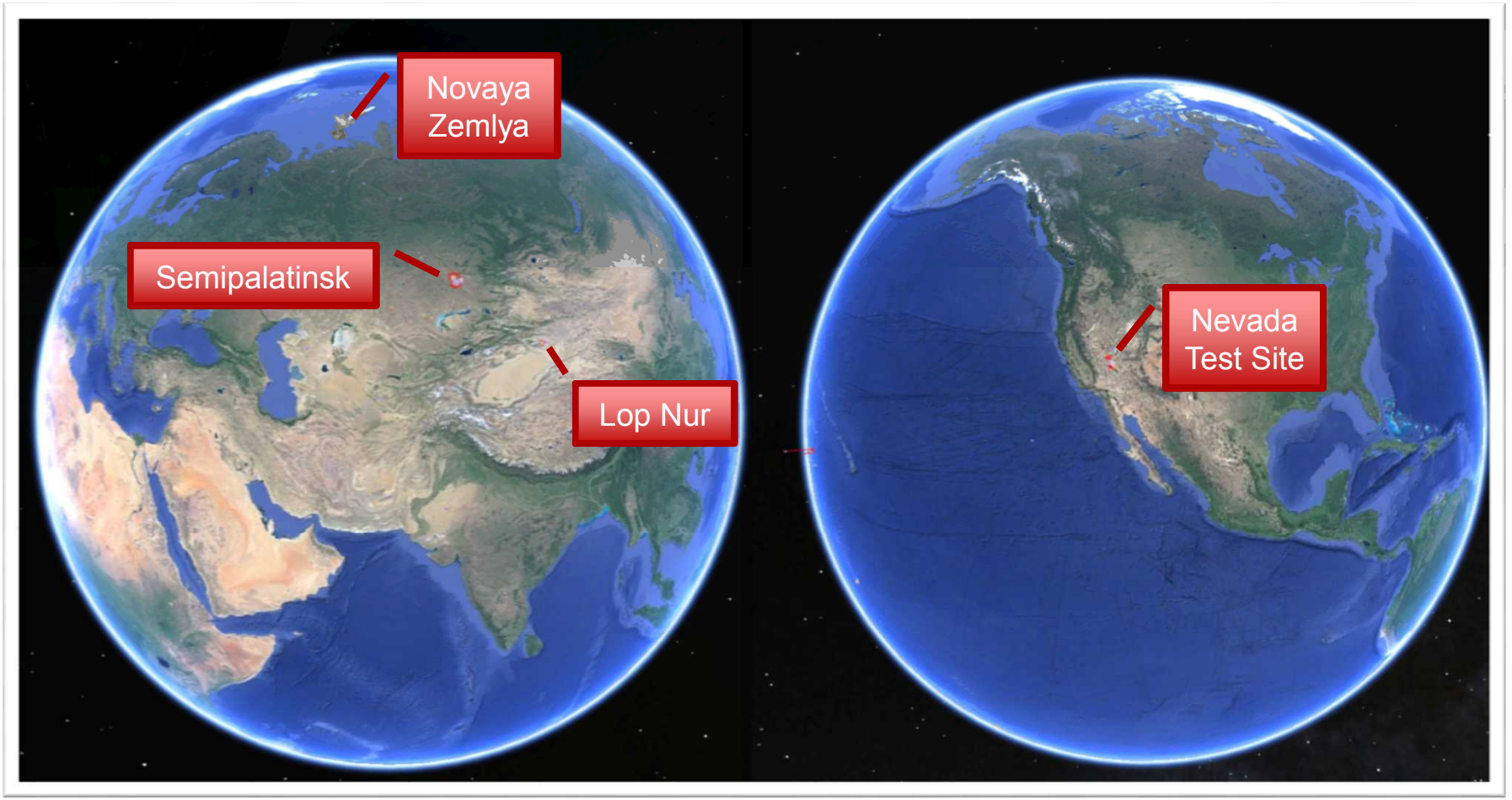
Modified from Selby et al. (2012)

- North Korea nuclear tests fall outside automated screening line for "suspicious" events
- This line is based on *empirical* evidence with limited breadth of experience
- Need new physics-based models



Experience is Limited

Vast majority of well-recorded tests from only four sites

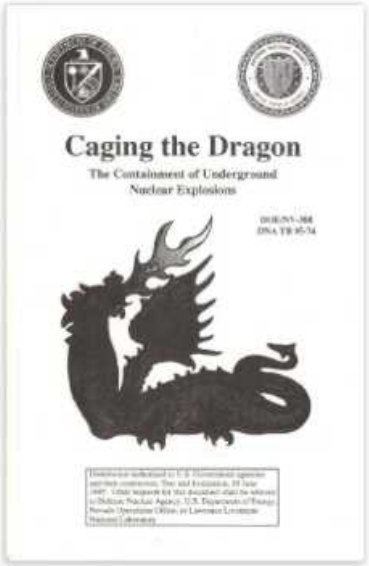


Testing Procedures Probably Similar Internationally

Sandia National Laboratories

Books | Advanced Search | New Releases | Best Sellers | The New York Times® Best Sellers | Children's Books | Textbooks | Textbook Rentals | Sell Us Your Books | Bes

‹ Back to search results for "caging the dragon"



See this image

Caging the Dragon: The Containment of Underground Nuclear Explosions (DOE/NV-388, DNA TR 95-74) Paperback – 1995

by James Carothers (Author)

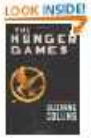
Be the first to review this item

› See all formats and editions

Paperback
from $5,000.00

1 Used from $5,000.00

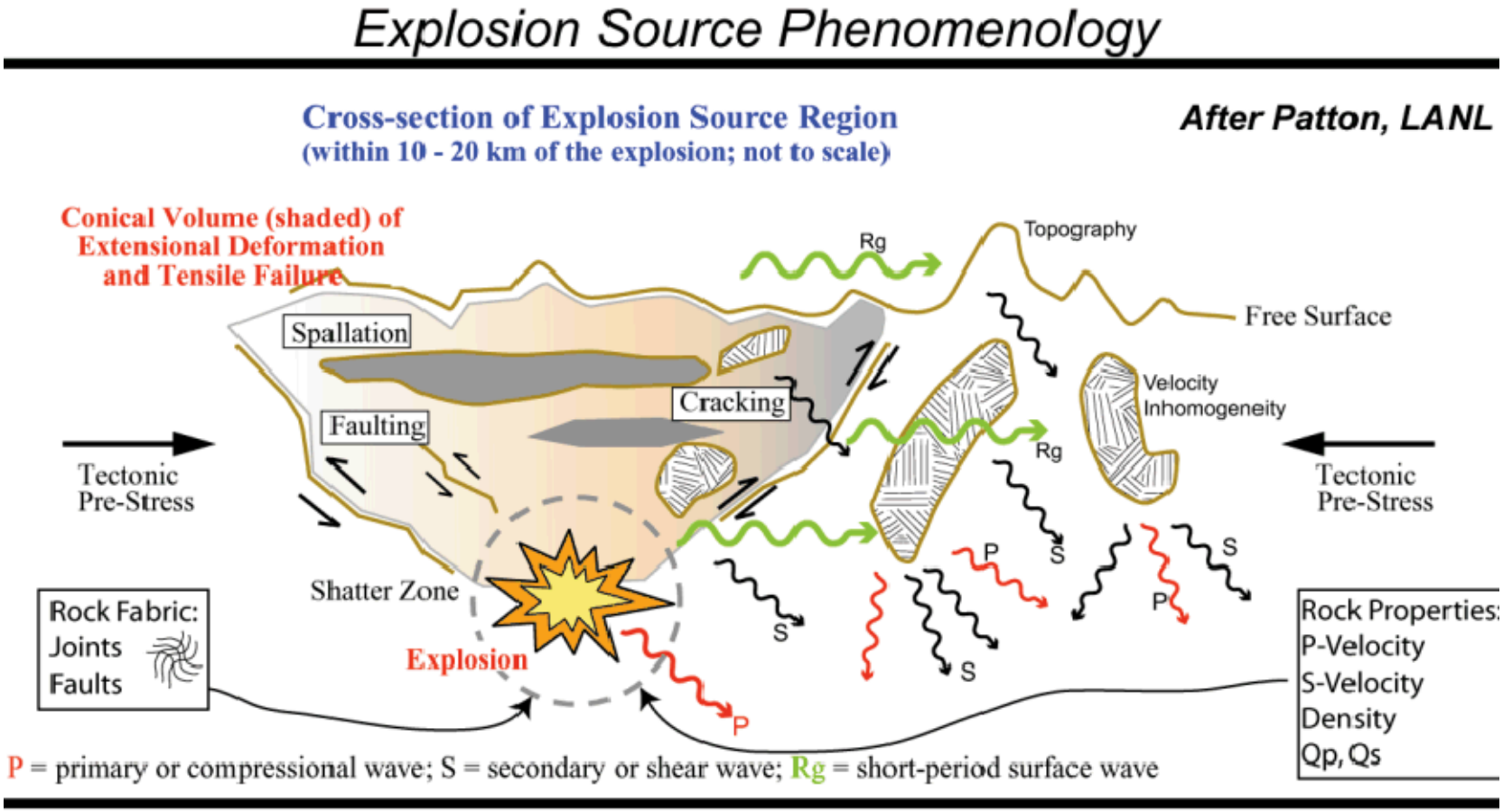
Note: *This item is only available from third-party sellers (see all offers).*



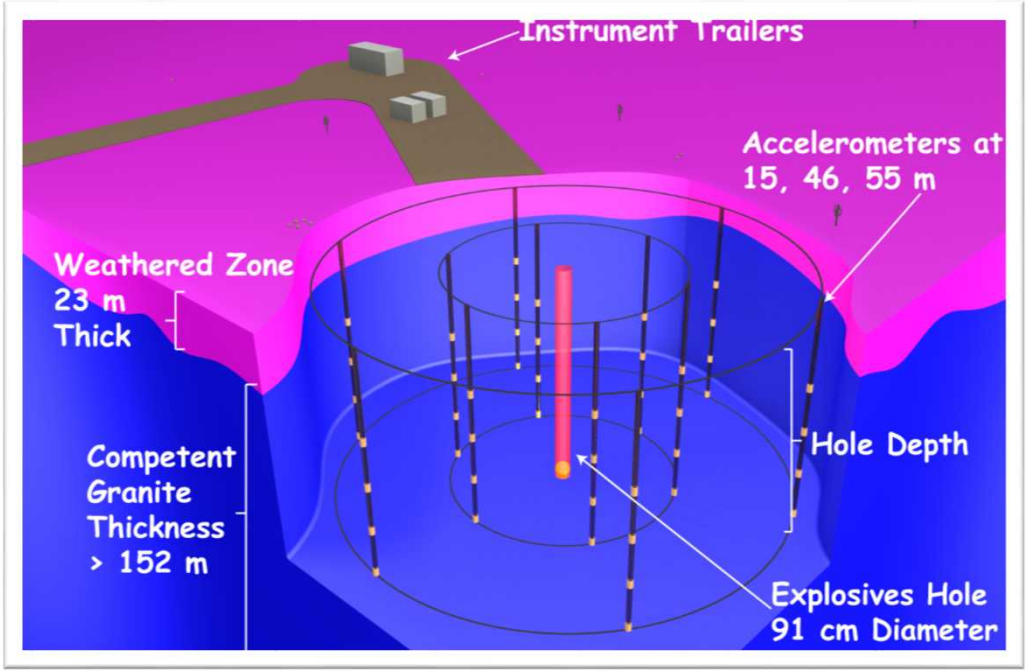
Top 20 lists in Books

View the top 20 best sellers of all time, the most reviewed books of all time and some of our editors' favorite picks. Learn more

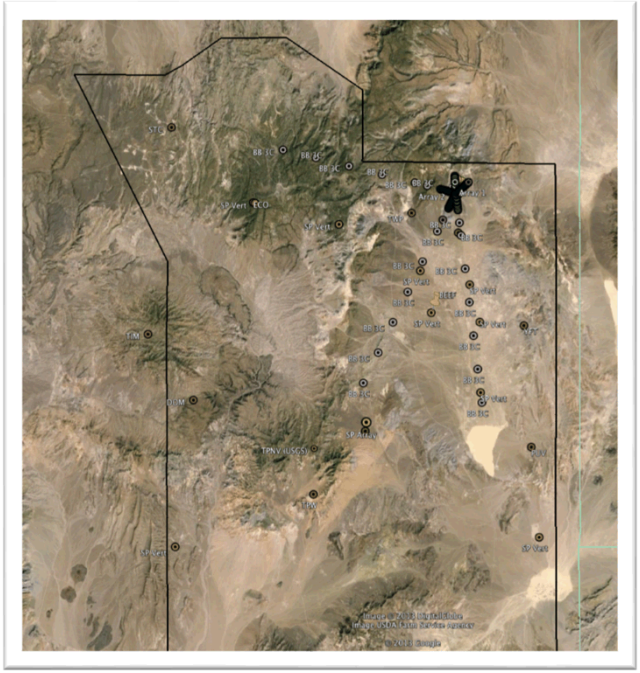
Known or Suspected Sources of Shear Energy



Experimental Layout



Near-Field Measurements

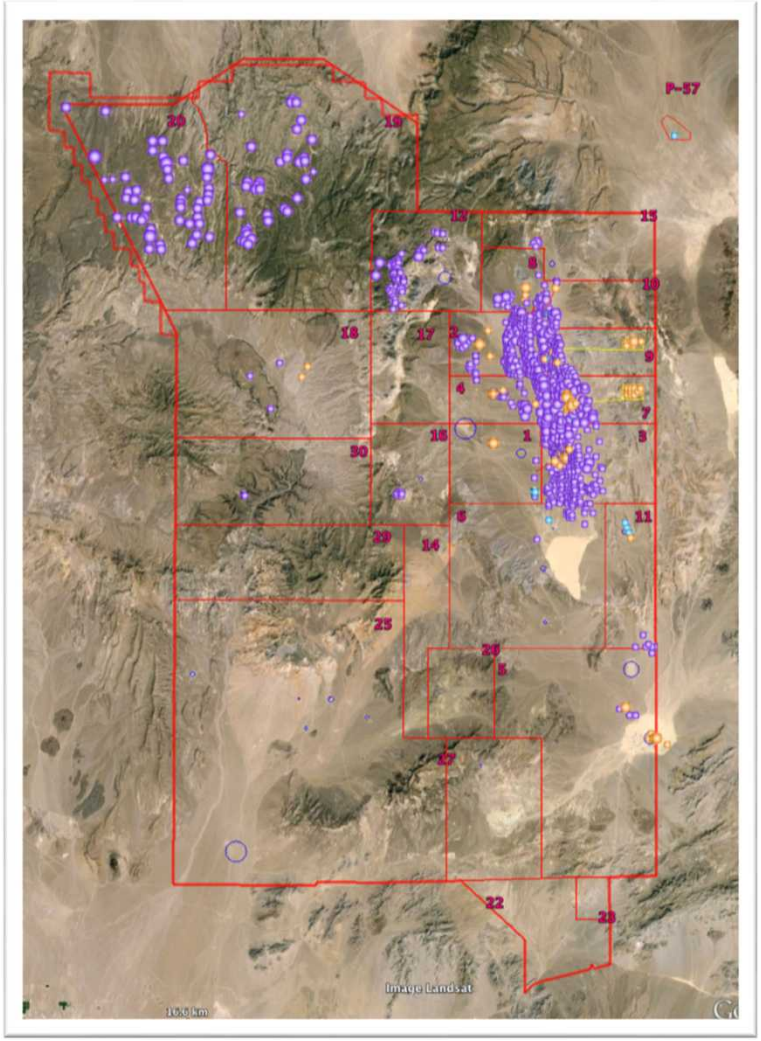


Far-Field Measurements

Where does the Seismic Hammer™ and Yucca Flat Come in?

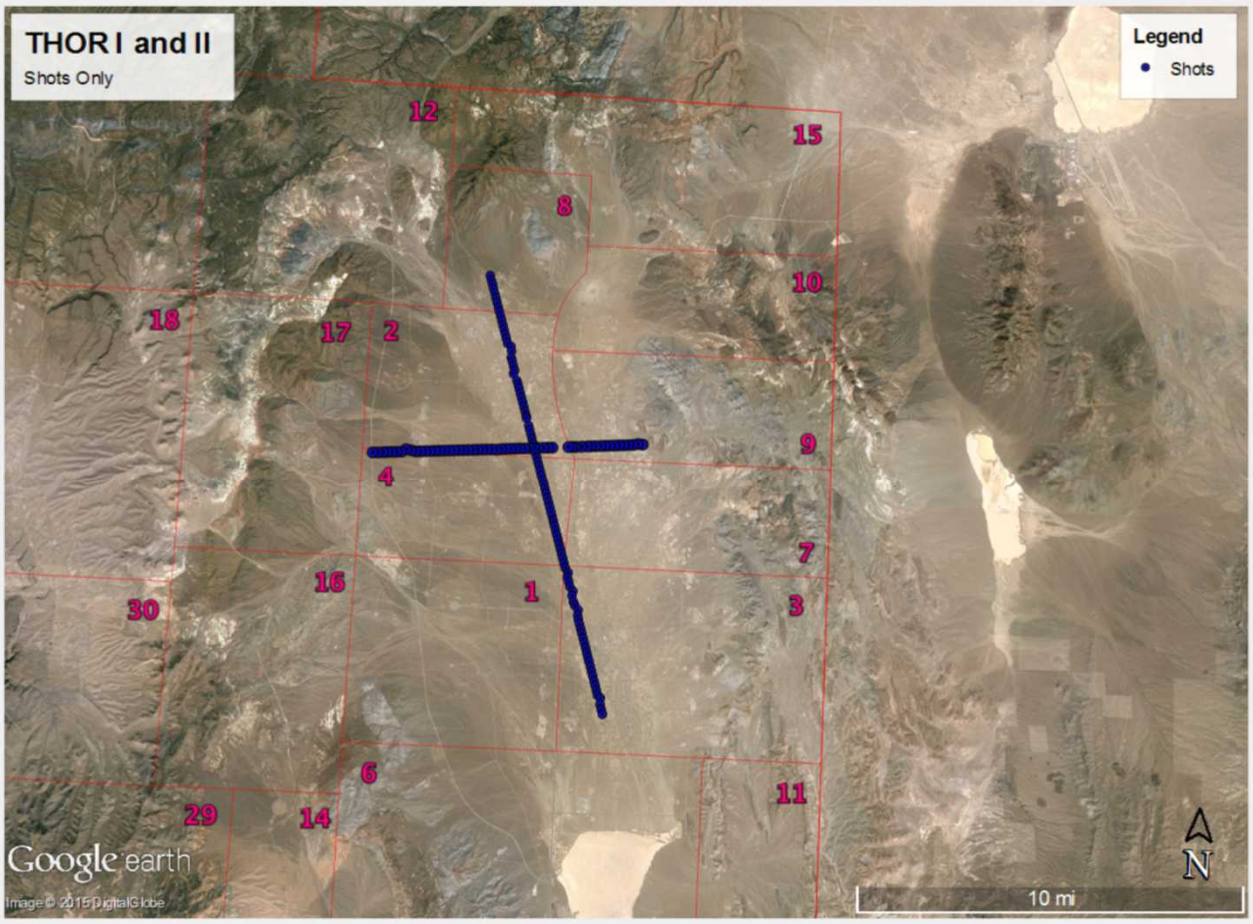
- SPE is moving to a different geologic setting
- Dry Alluvium Geology (DAG)
- The need for better geophysical characterization as input to models was demonstrated by SPE

Yucca Flat



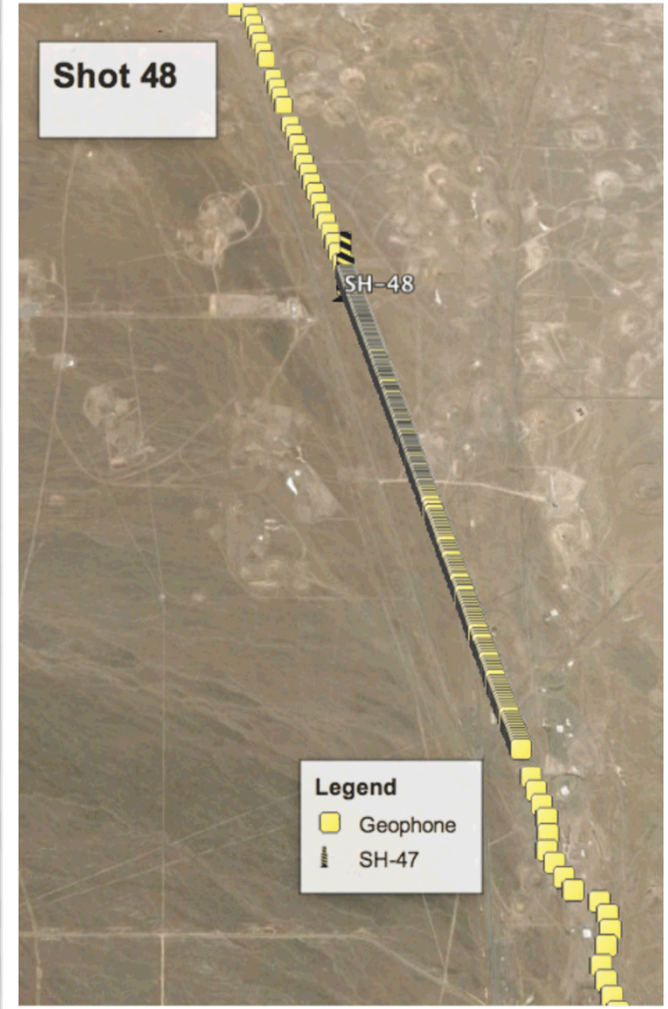
- Tertiary extensional basin
  - Alluvium overlaying Miocene volcanic tuffs and Paleozoic carbonate rocks
  - Maximum depth-to-Pz approximately 1 km
- Location of over 80% of CONUS nuclear tests (739)

Thor 1 and Thor 2

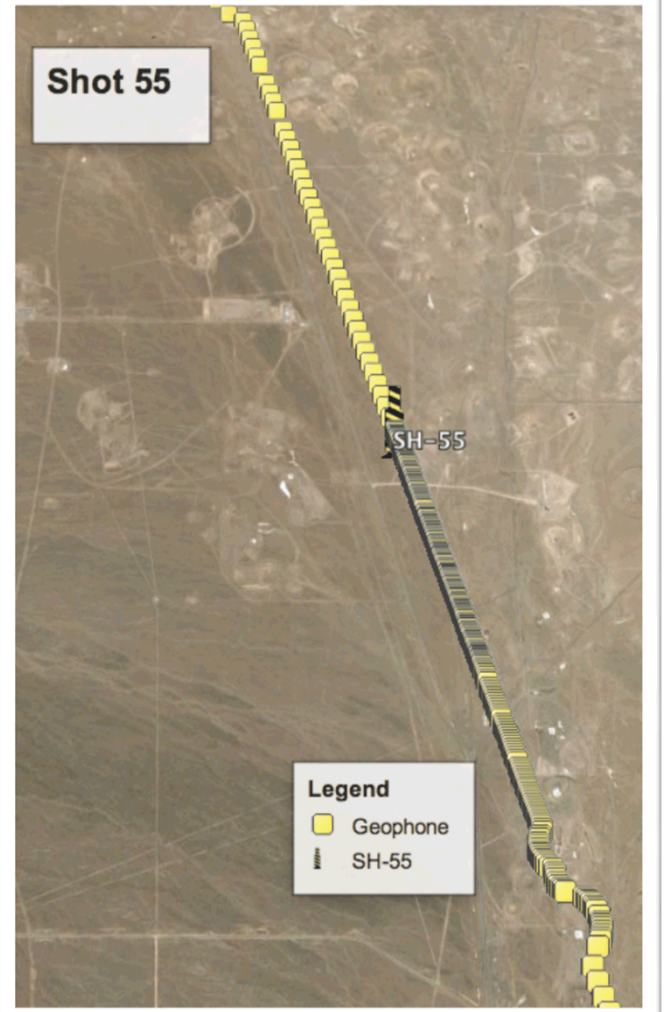


- 96 Shot points (Thor 1),
- 58 Shot Points (Thor 2)
- At least 32 hits per shot point
- Shots spaced every 200 m
- 360-370 receivers per shot
- Variable spacing for geophones
  - 10 m < 2 km from source
  - 20 m 2-4 km
  - 100 m 4+ km
  - Leave behind 100 m
- Hit repetition rate: ~25 s
- Station rate:
  - THOR: ~25-30 minutes
  - FREY: ~8 min

Thor Sensor Layout



- Variable sensor spacing:
- 10 m < 2 km from source
- 20 m 2-4 km
- 100 m 4+ km
- Leave behind 100 m



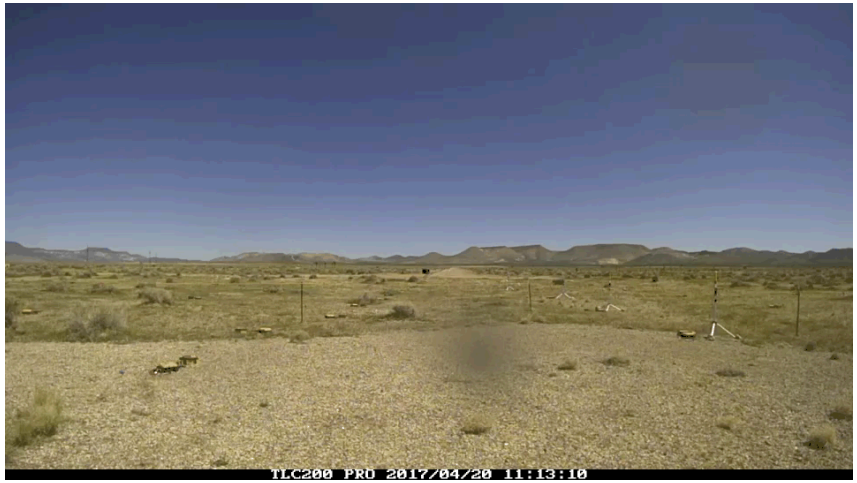
Sandia National Laboratories

SOURCE CHARACTERISTICS

Slow Motion Movie

Pick and Carry Configuration

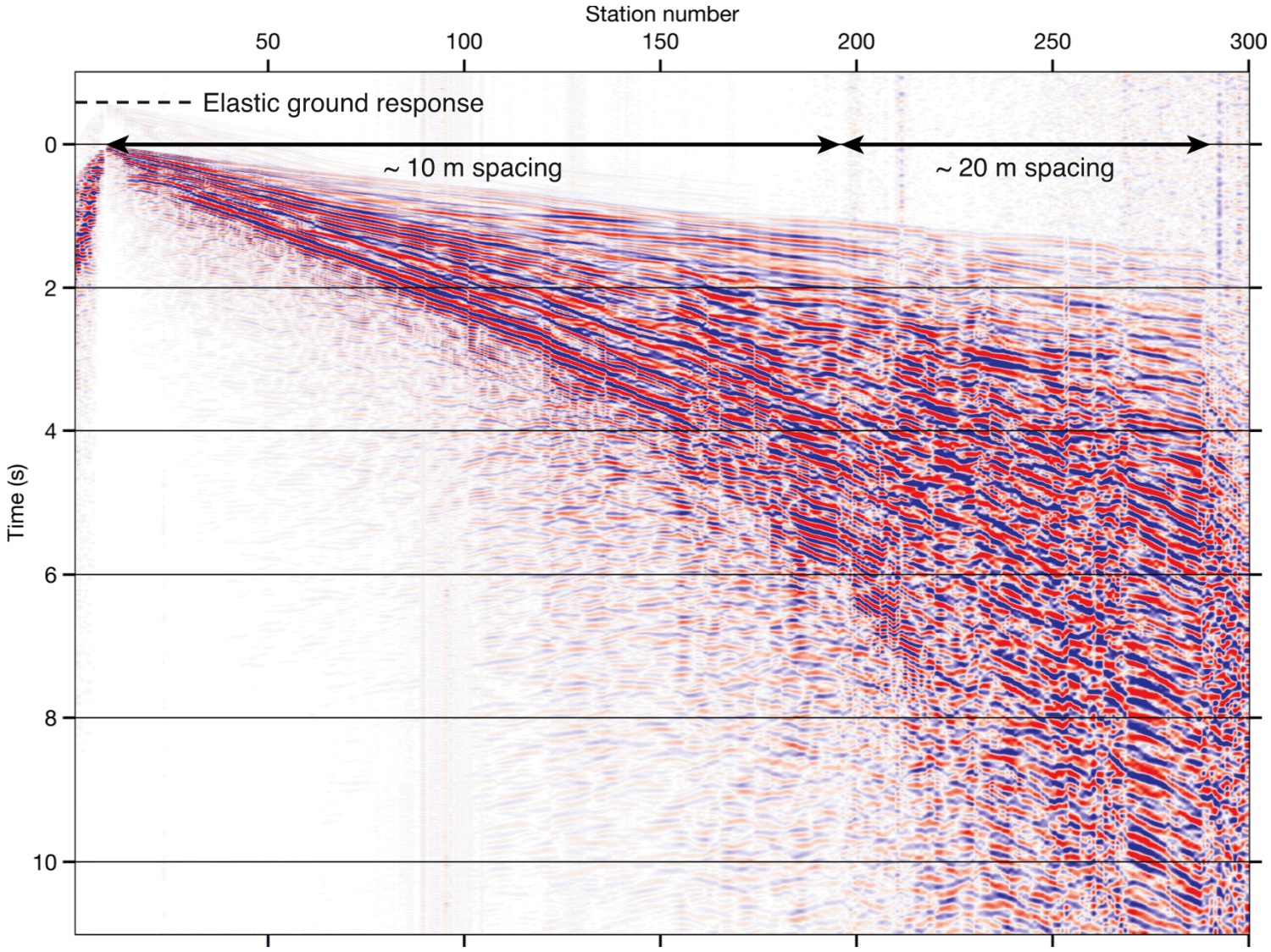
Hammer in “Frey” Configuration



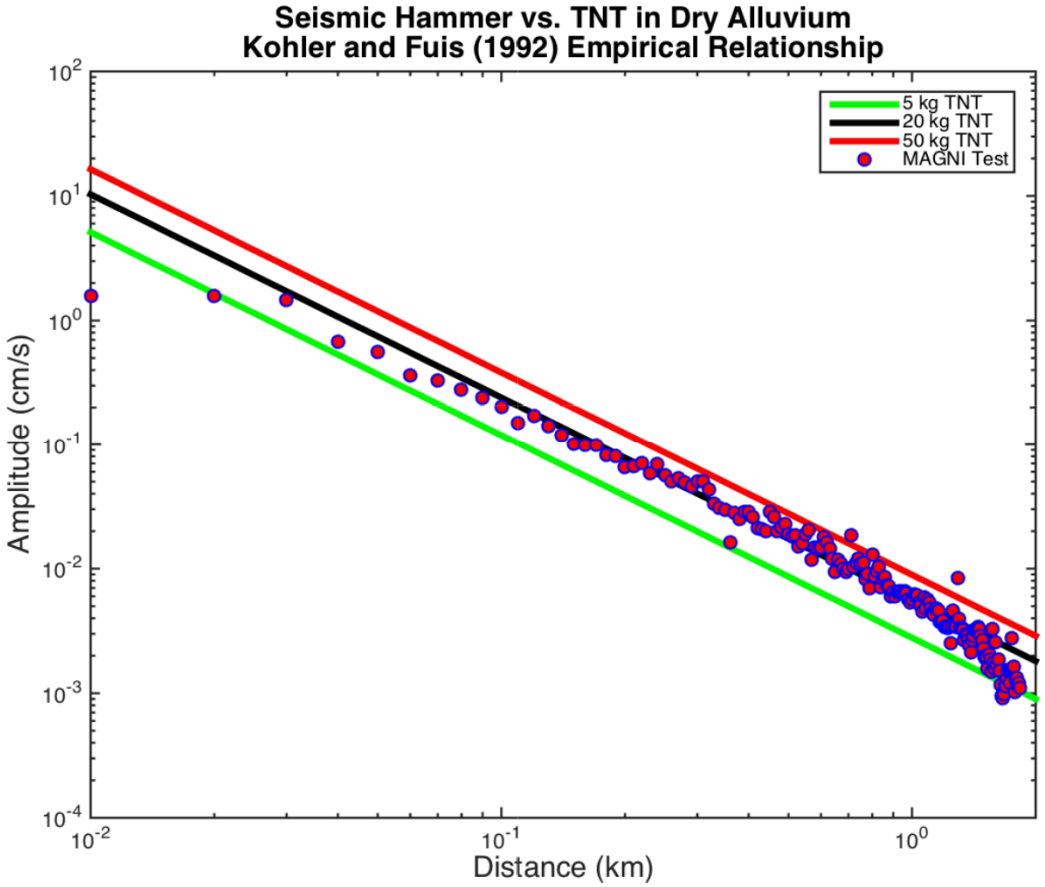
Pick and Carry Movie

- Triples the station repetition rate from ~30 minutes to ~8 minutes

Example Stacked Data



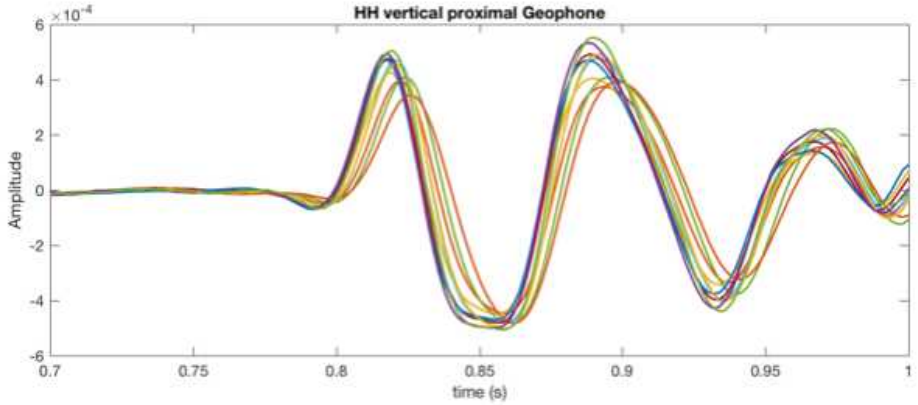
Hammer-Explosives Equivalent

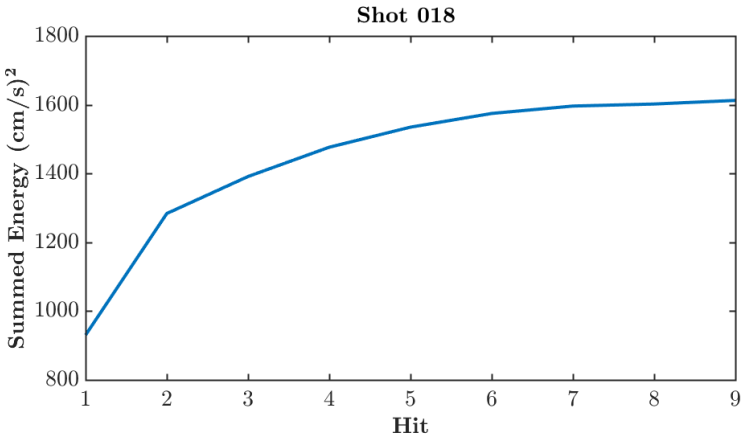


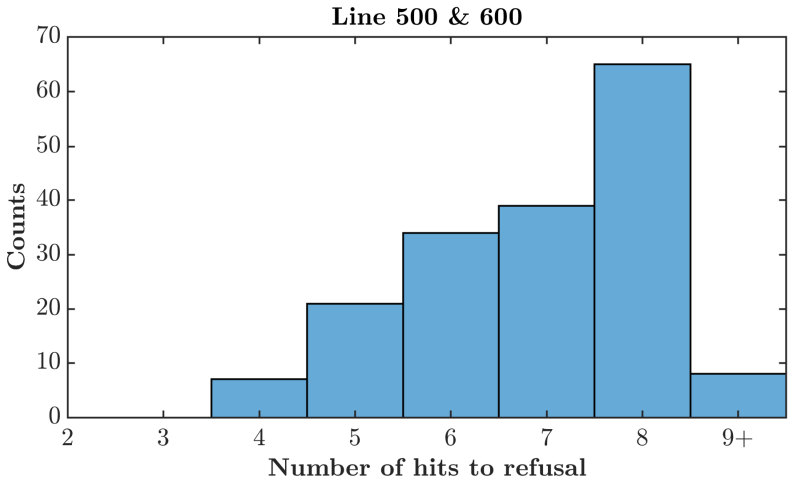
- Seismic Hammer™ yield same peak-to-peak ground particle velocity as 20 kg TNT (in alluvium)
- Caveat: This most likely is from surface waves, not body waves

SH = 0.19 MJ potential energy; 20 kg TNT = 80 MJ
Therefore the SH is ≈ 420 x more seismically efficient

Source Timing and Energy Issues

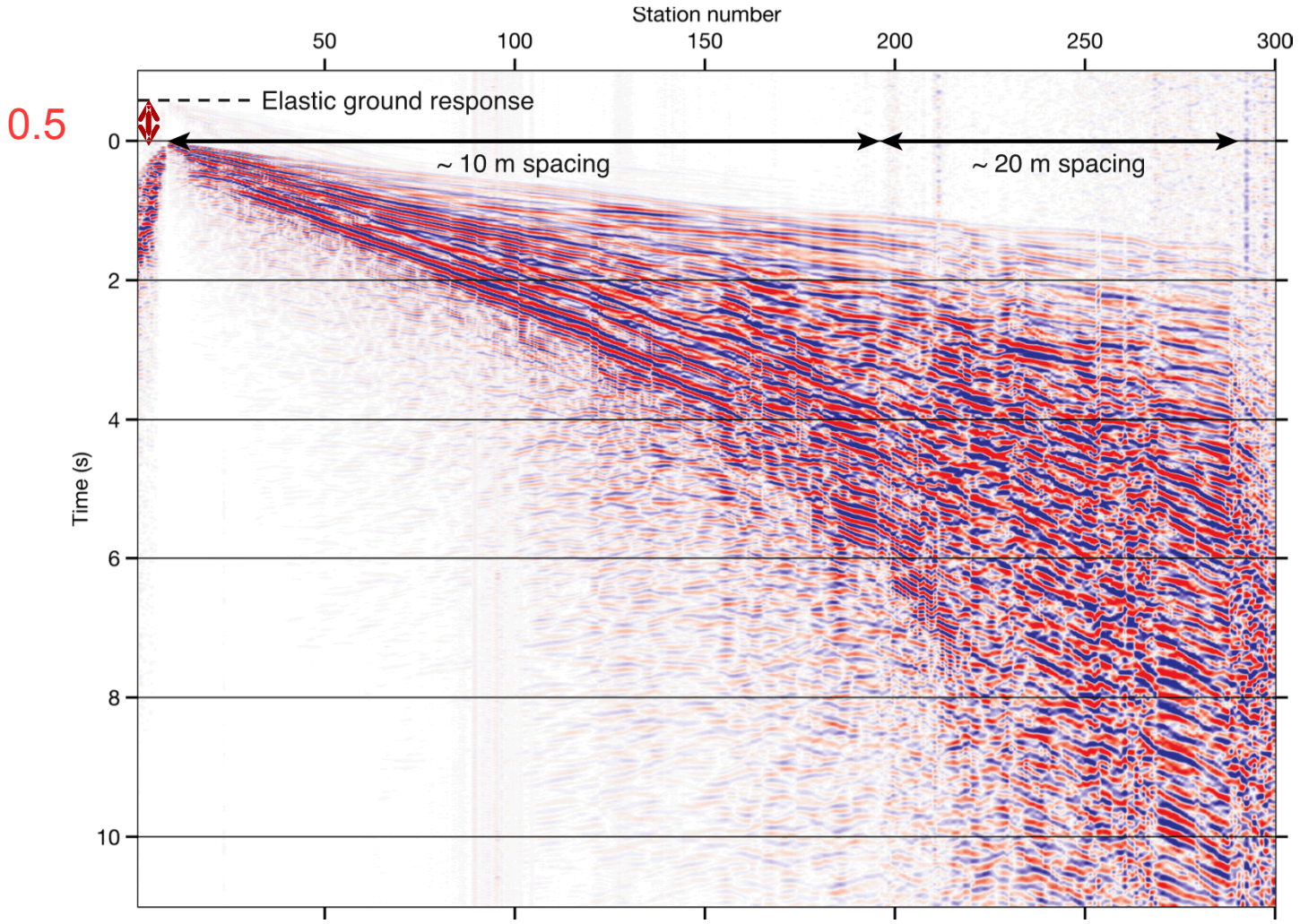




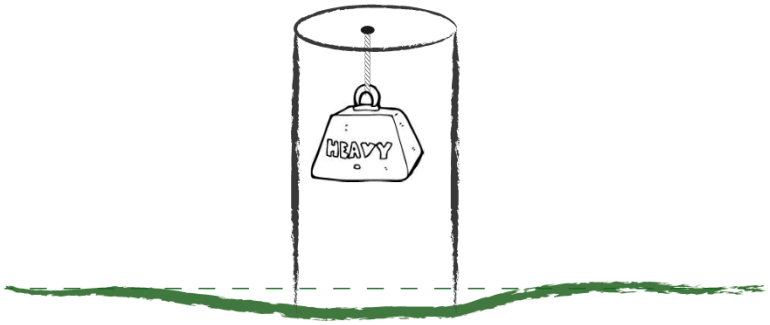


- Multiple hits at same source point are needed before waveform stabilizes
  - "Driven to Refusal"

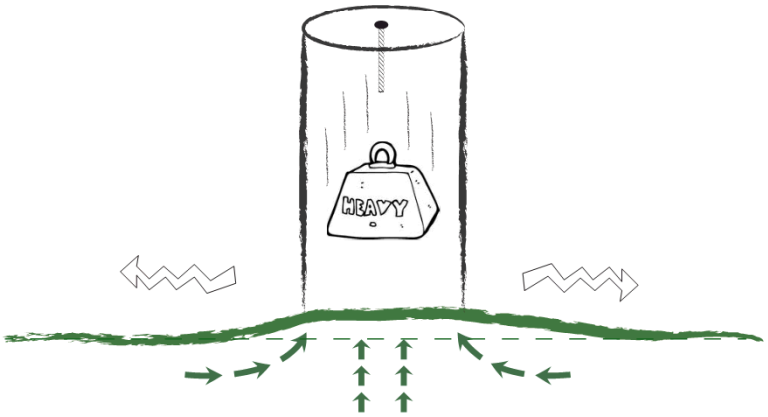
Unloading Precursor



Elastic Rebound Seismic Source

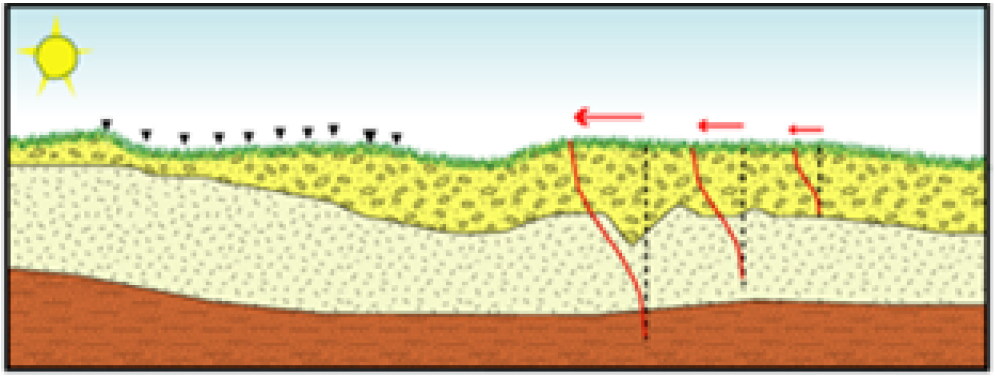


Ground level depressed statically



Ground level rebounds, overshooting equilibrium, radiating seismic energy

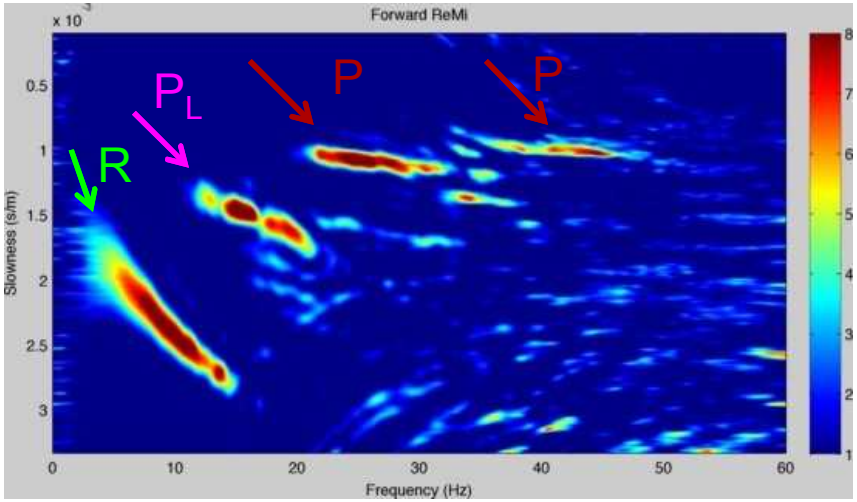
Surface Wave Measurements



Rayleigh Wave Propagation

Surface waves travel at the velocities proportional to their wavelength (or frequency)

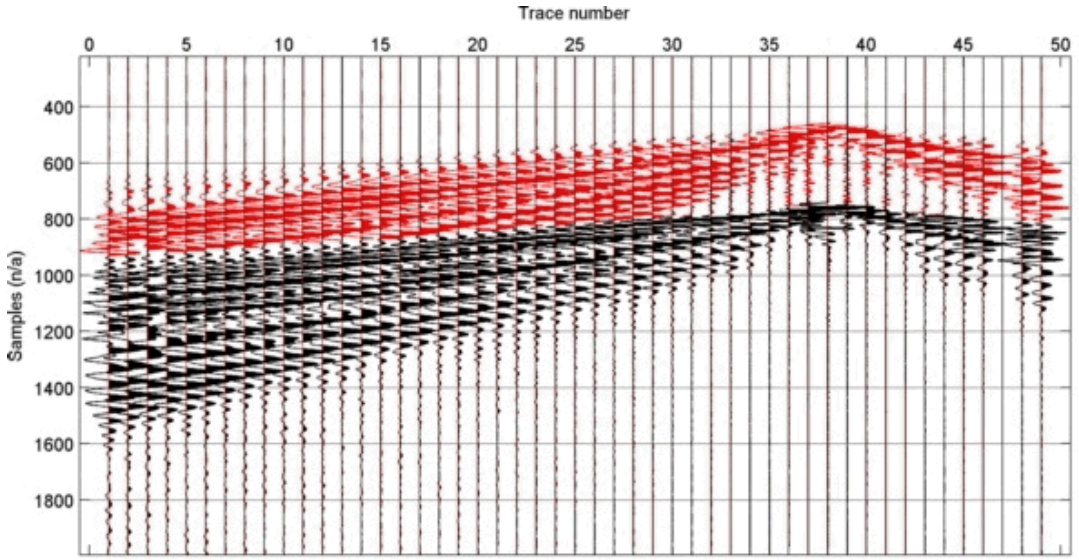
The Seismic Hammer™ has produced some of the nicest and most unusual ReMi plots I have seen.

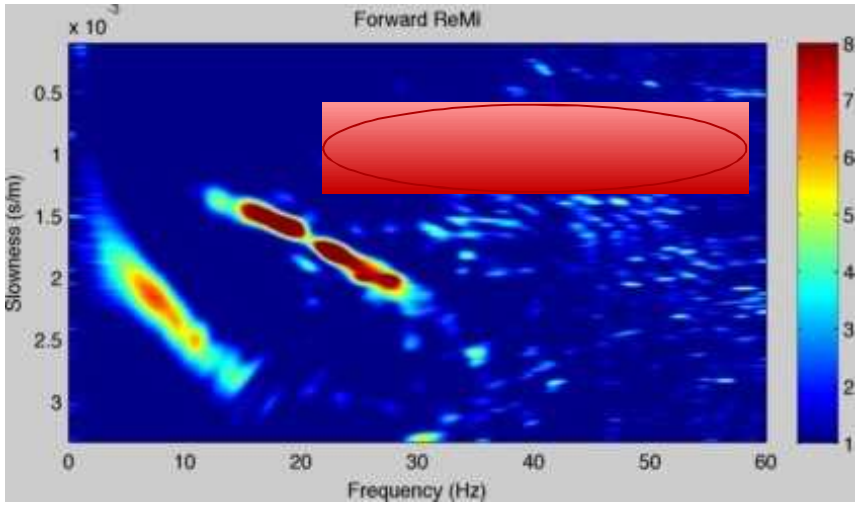


ReMi Slowness-Frequency Plot

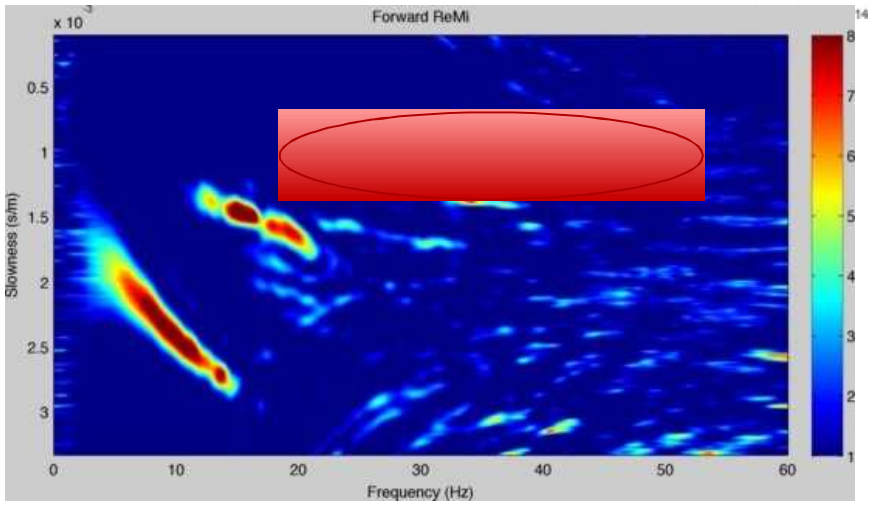
Elastic Rebound Seismic Source

- Red is independently scaled precursor
  - Represents ground elastic-rebound of 13,000 kg unloading
- Black starts at hammer-plate impact





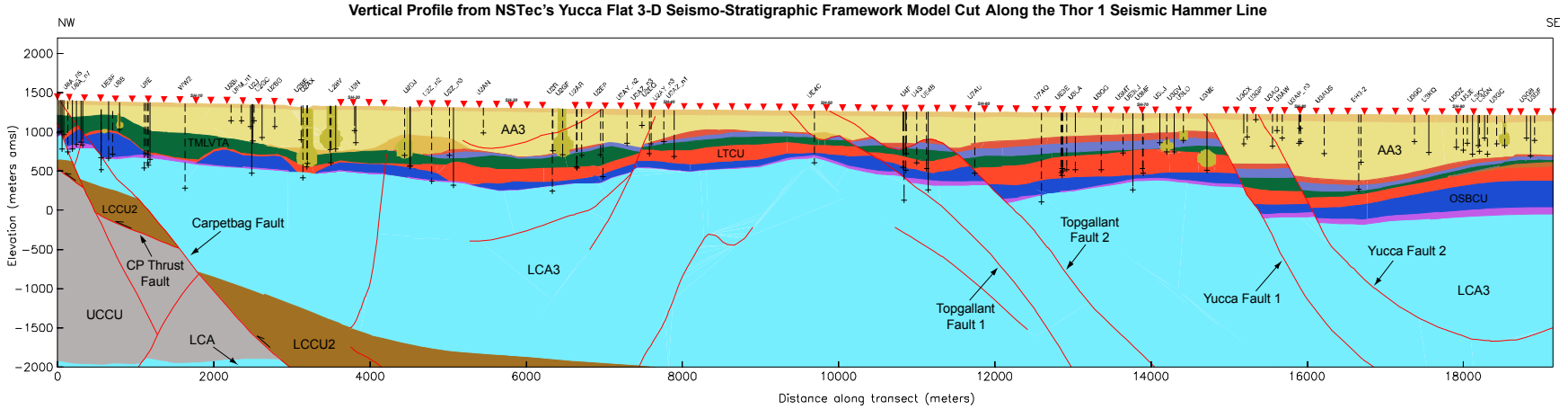
Pre-impact



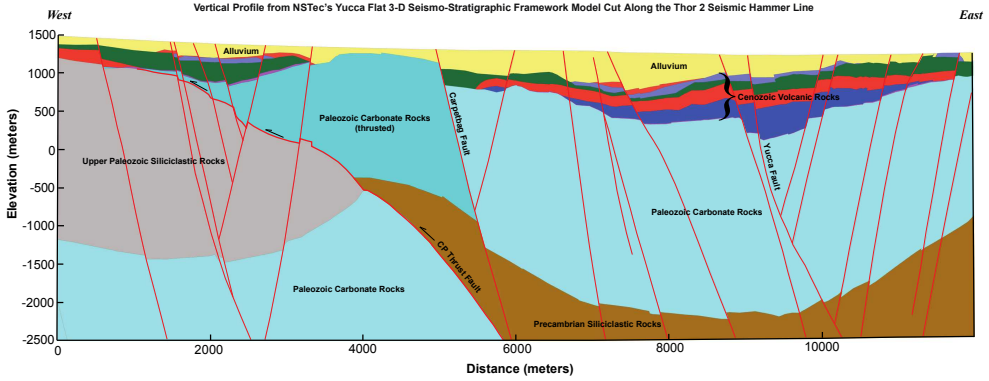
Post-impact

P-WAVE CHARACTERIZATION RESULTS

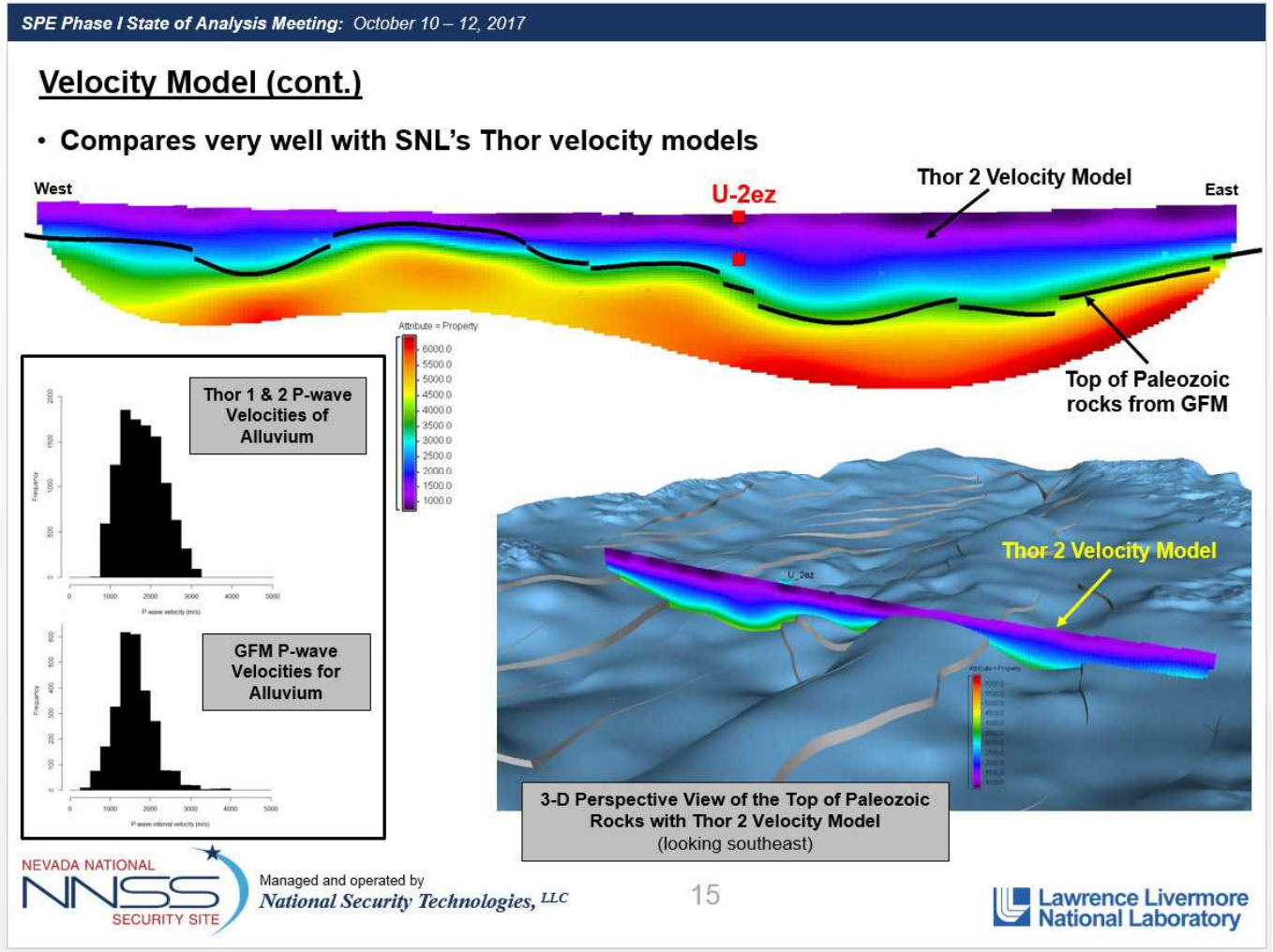
Thor 1 Geologic Cross Section



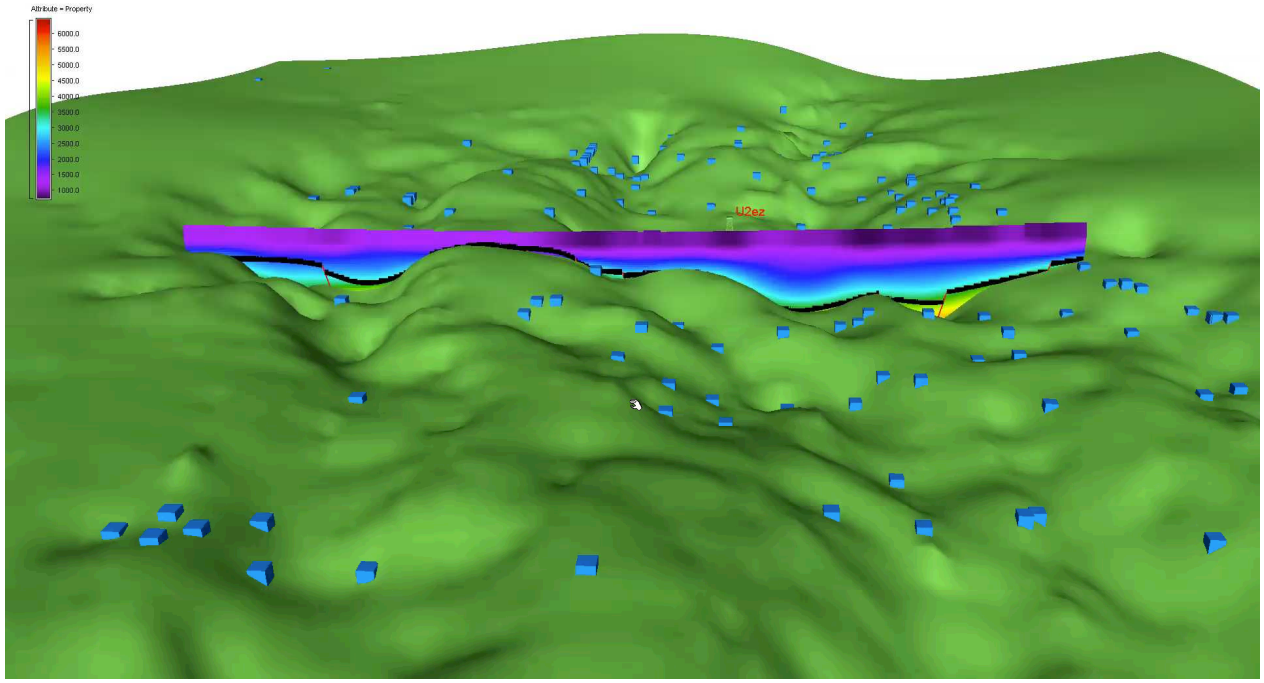
Figures Courtesy Lance Prothro, NSTec



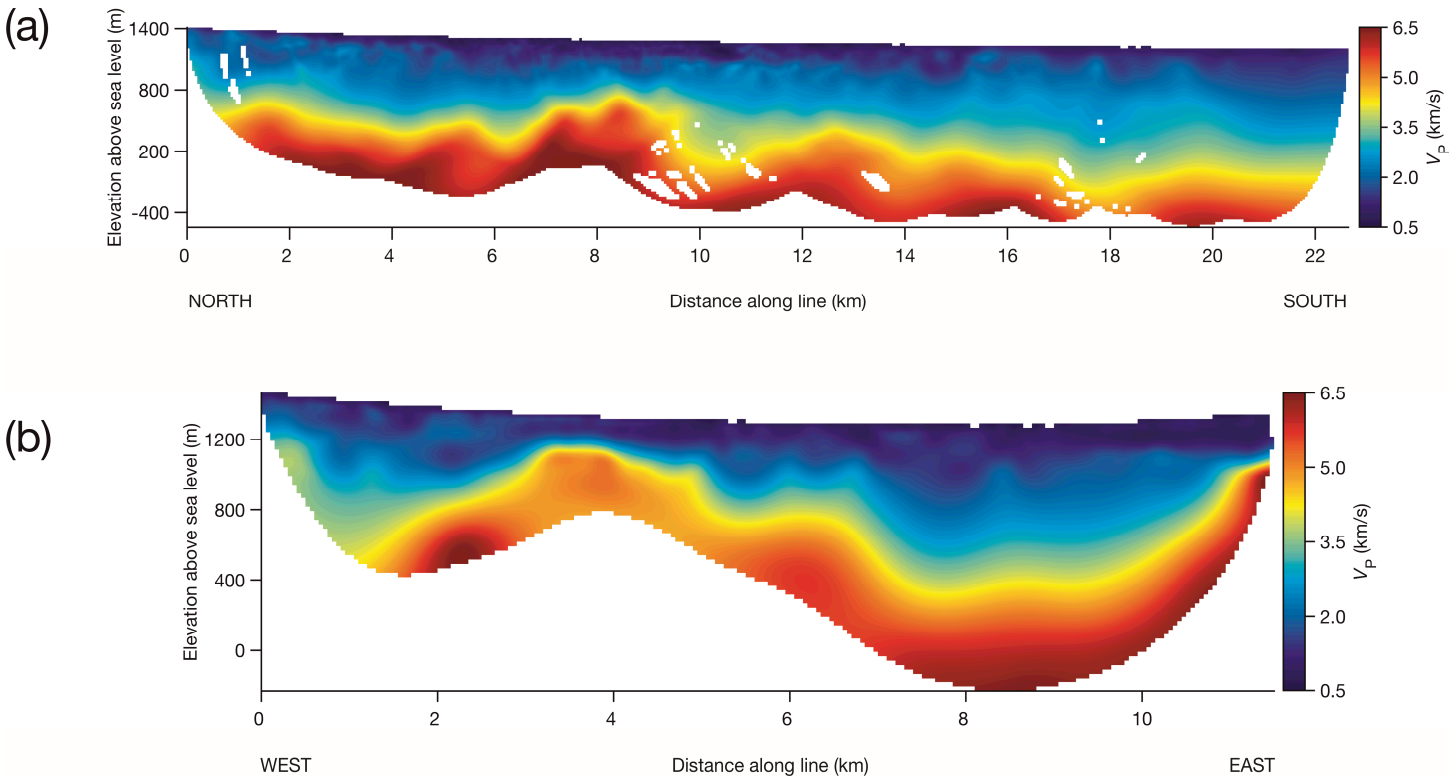
Thor 2 Similarities to GFM Model



Thor 2 Similarities to GFM Model



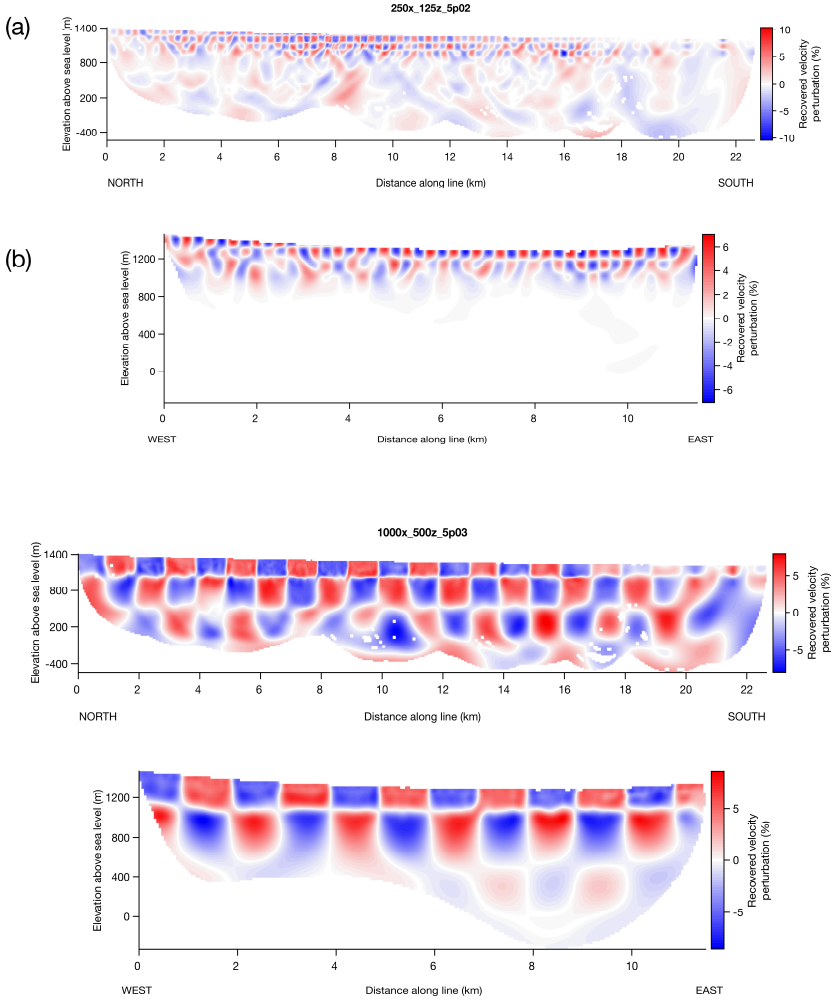
Vp Results -- Rough Version

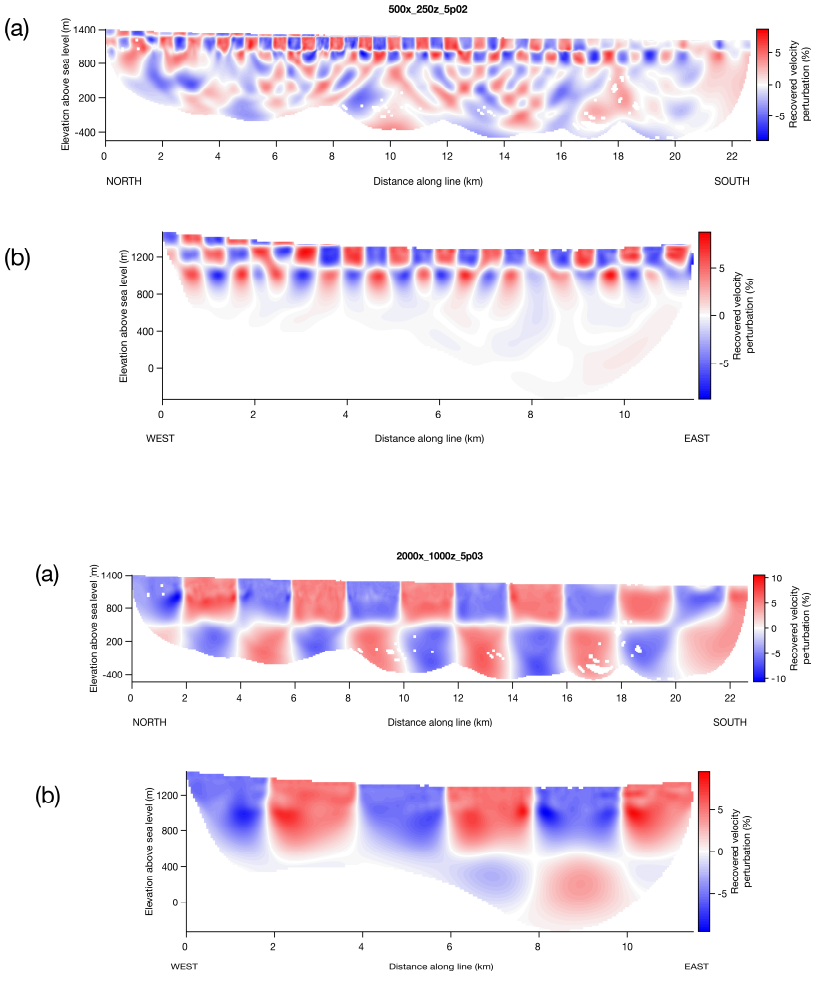


km/s

- Over 24,000 (T1) and 17,600 (T2) traveltime picks from Seismic Hammer™
- 924 traveltime picks from nearby emplacement hole surveys
  - Picks were weighted inversely proportional from distance to receiver line
- Tomographic grid spacing 50x50x25 m
- Depth-dependent smoothing
- Total rms error = 3 ms

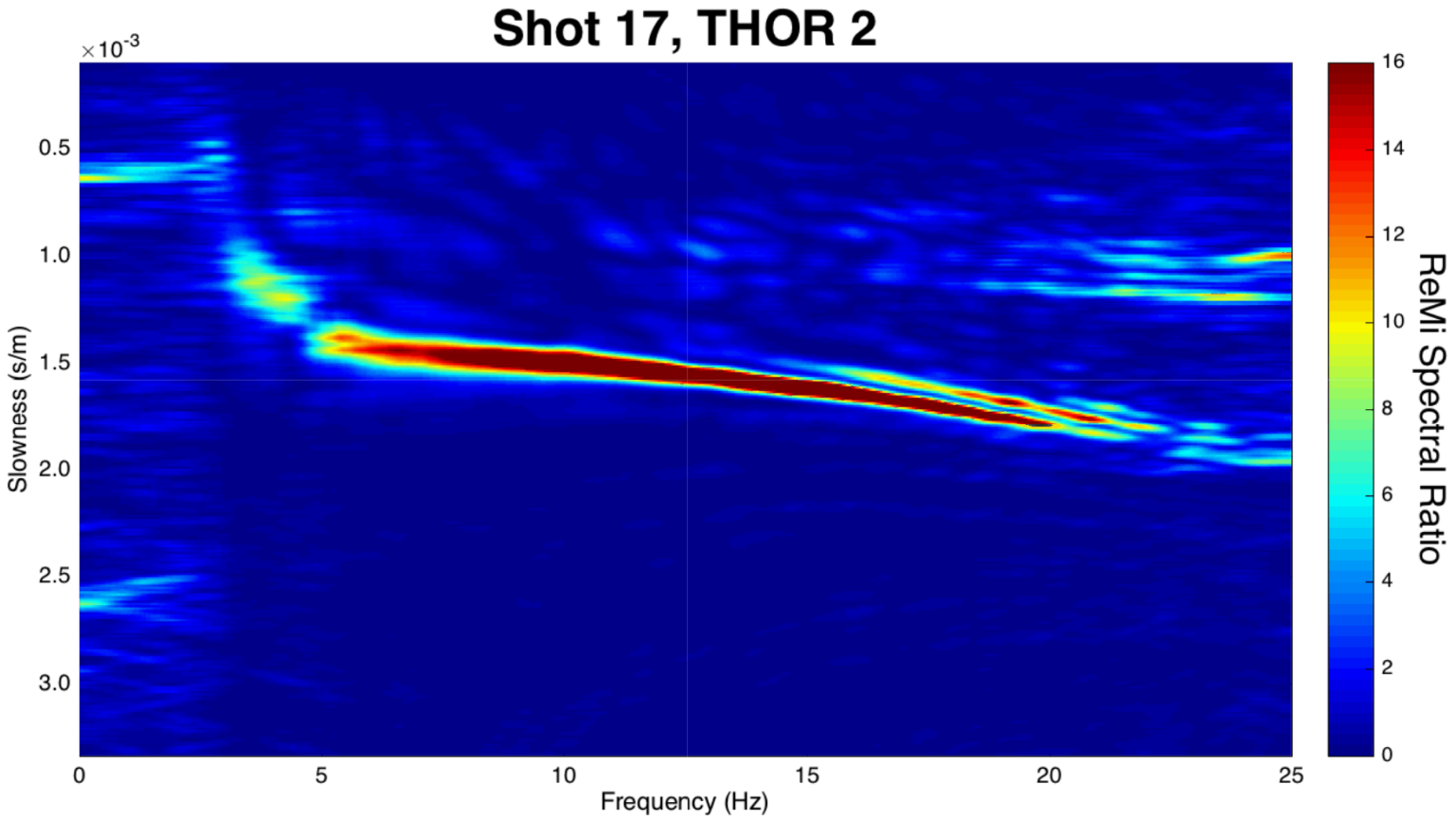
Checkerboard Resolution Tests (Including Picking Error)



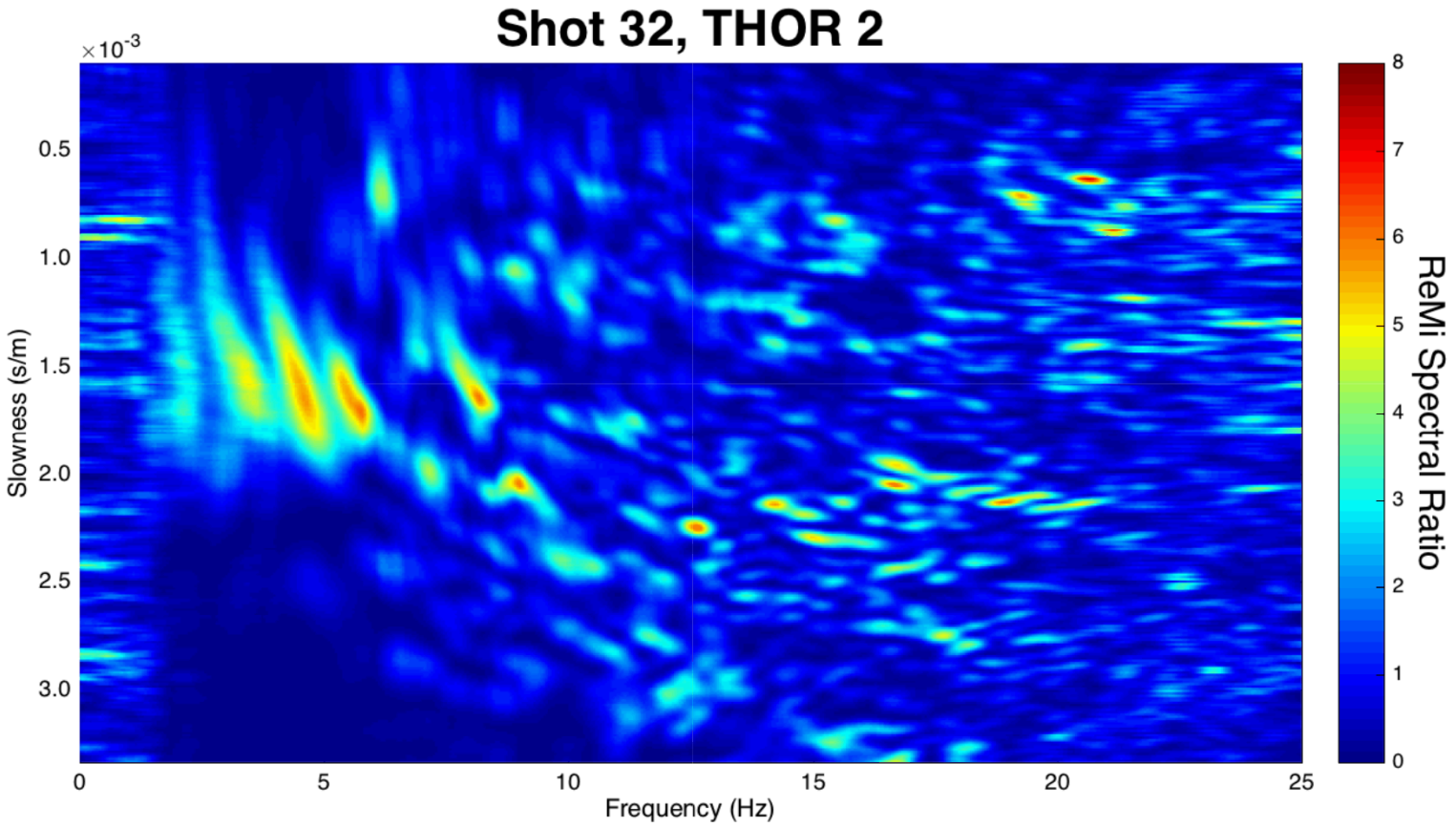


S-WAVE CHARACTERIZATION RESULTS

Good ReMi Data

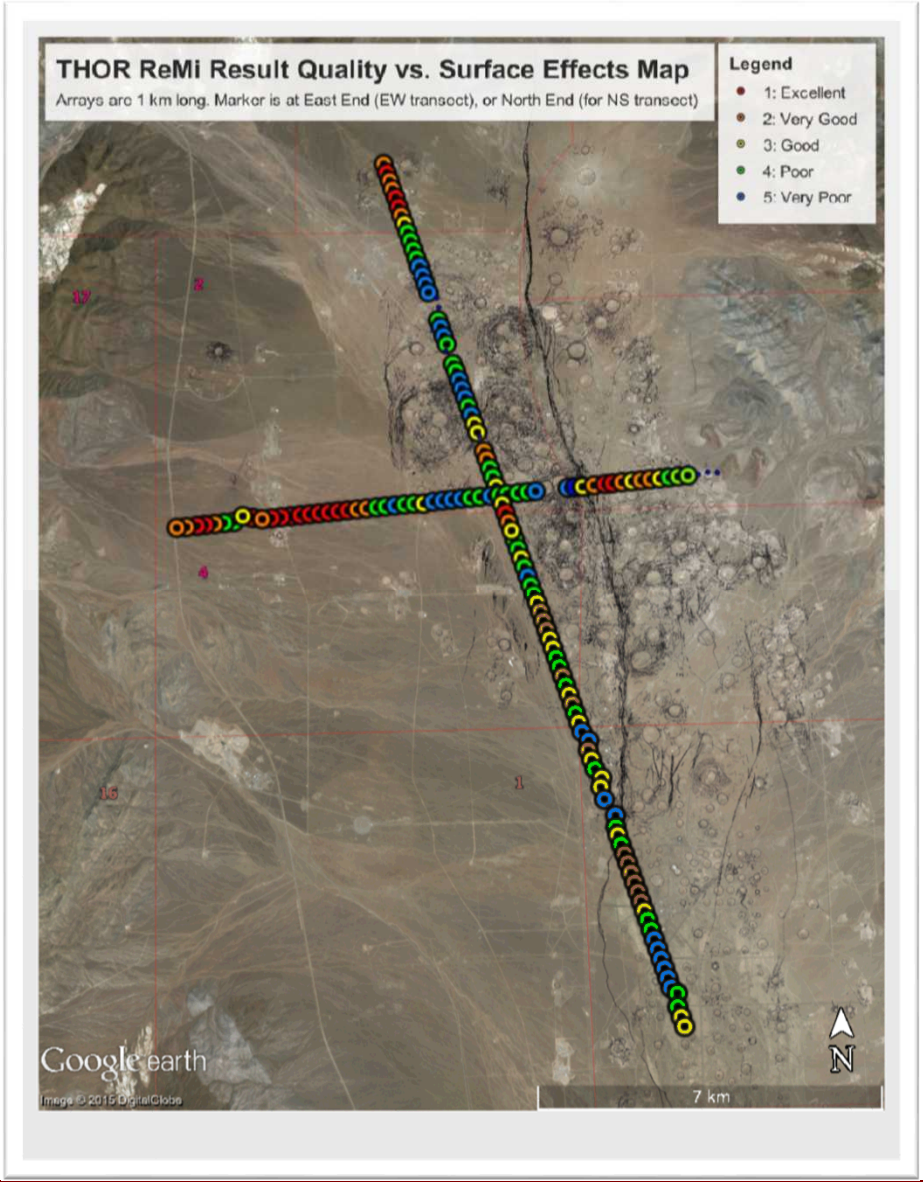


Bad ReMi Data

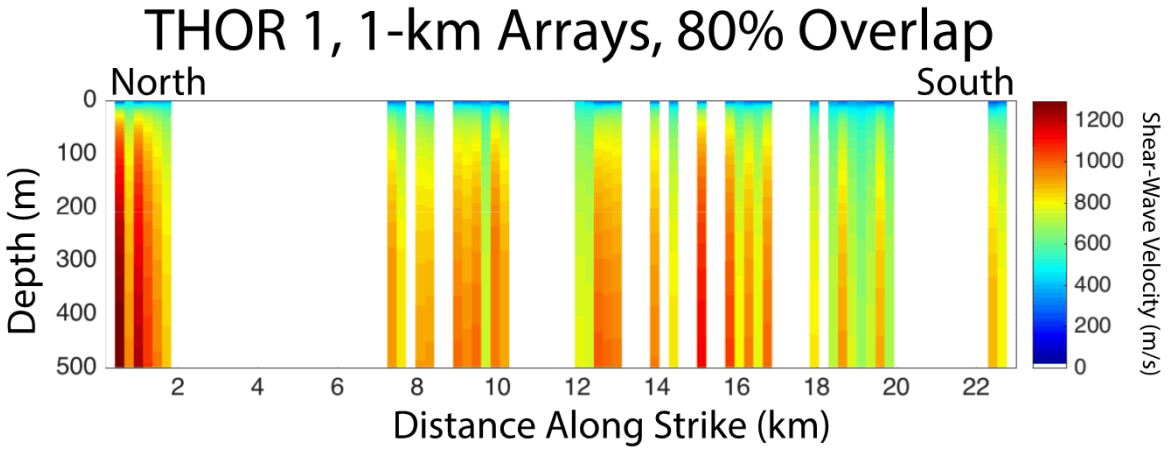


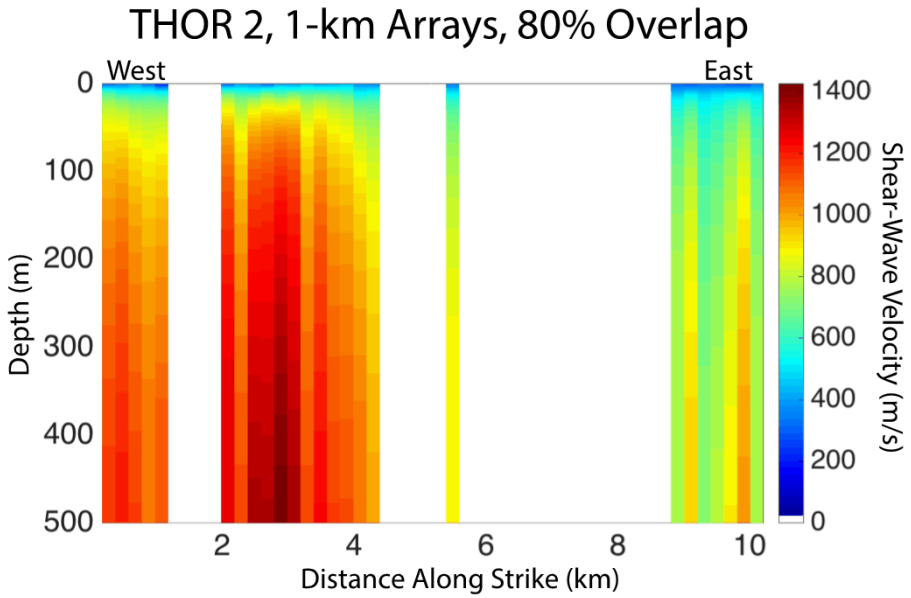
ReMi Quality Map

- Fine black lines are mapped surface effects (Grasso, 2000)

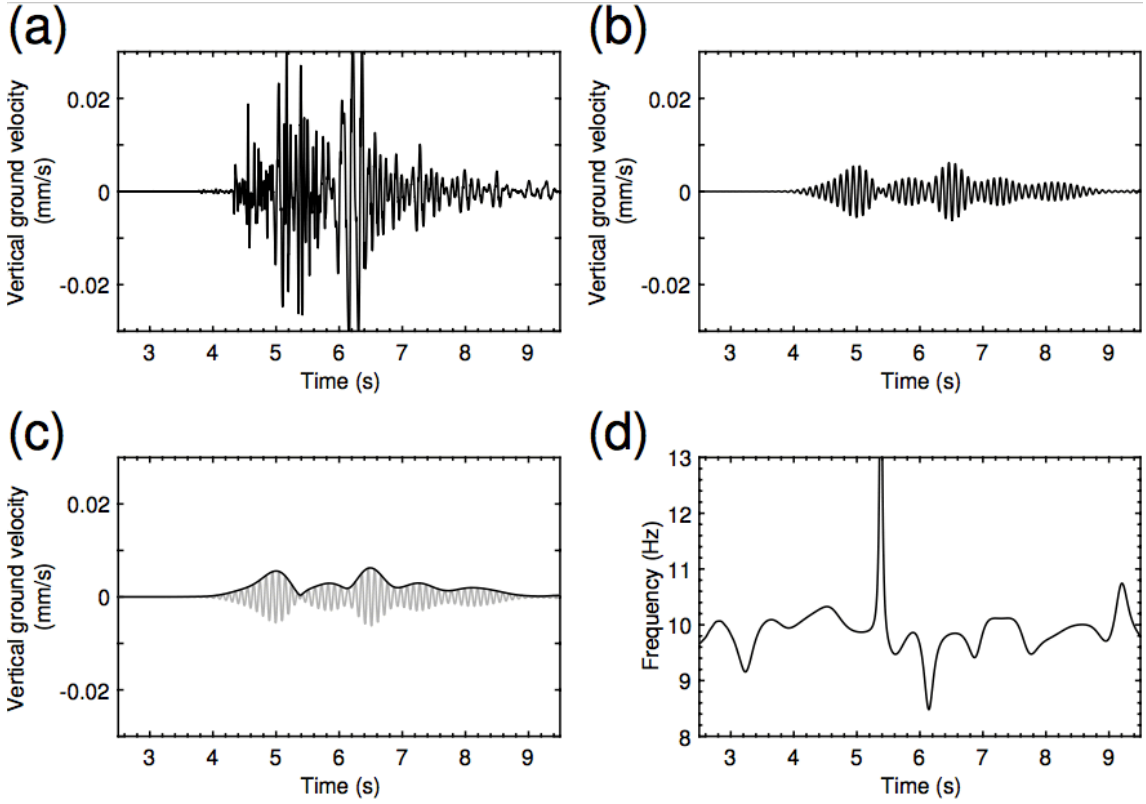


Thor ReMi Results





New Tactic – Group-Wave Tomography



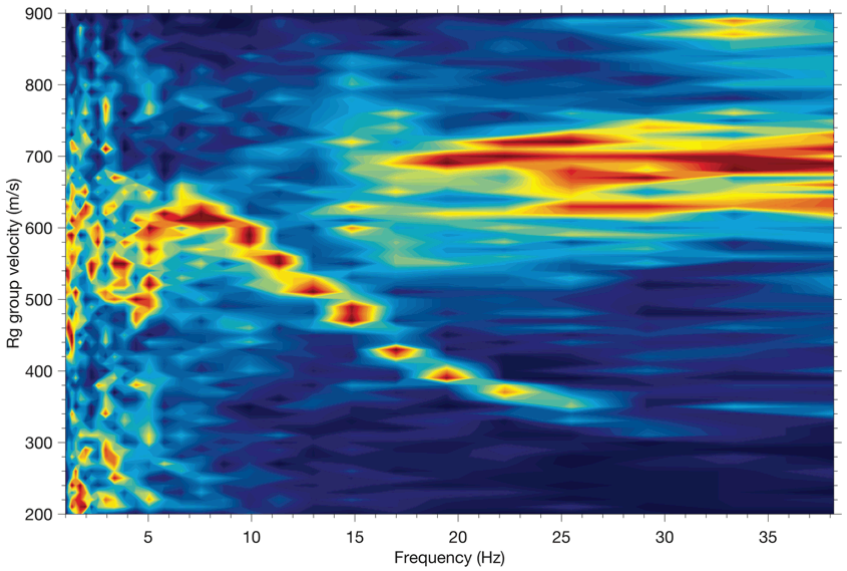
A) Raw Trace

B) Gaussian Filter

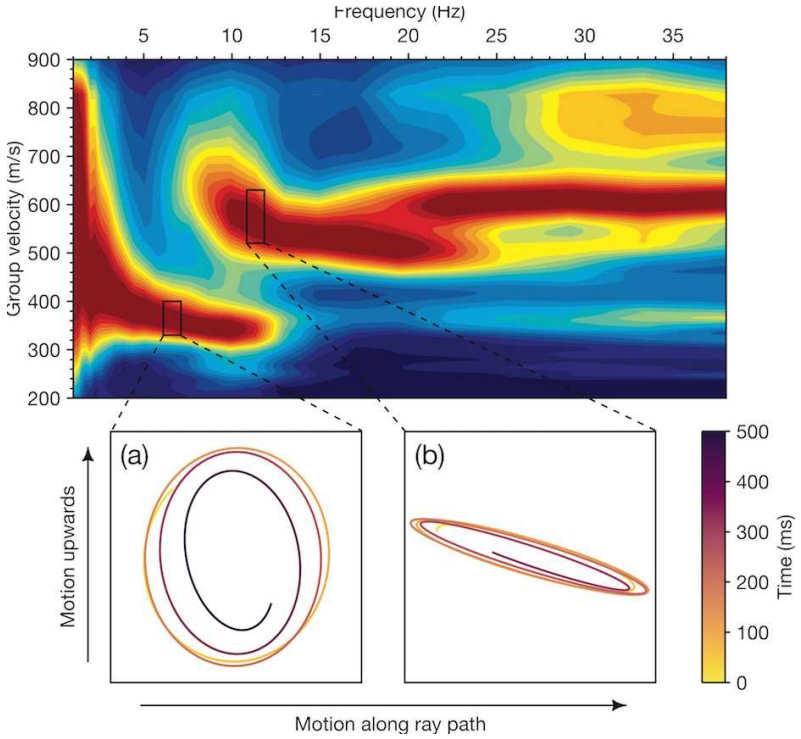
C) Instantaneous Amplitude

D) Instantaneous Phase

MFT Multiple Filter Technique



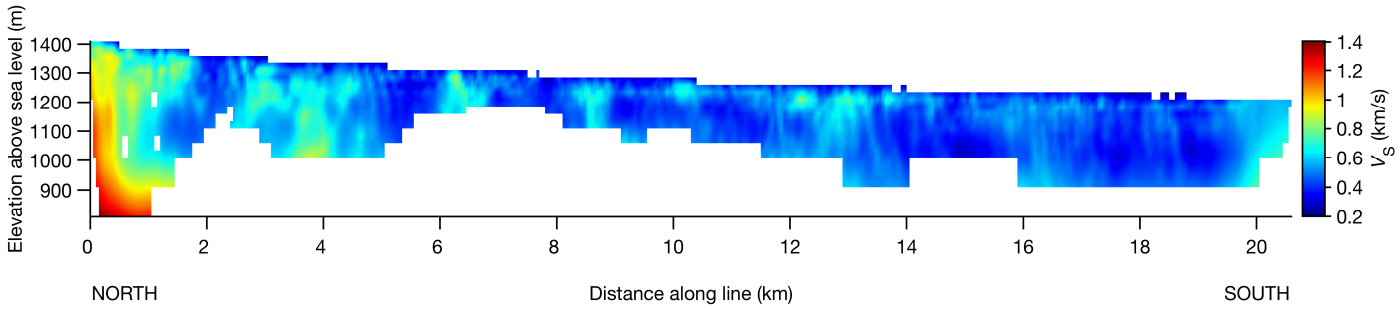
FTAN – Single Trace



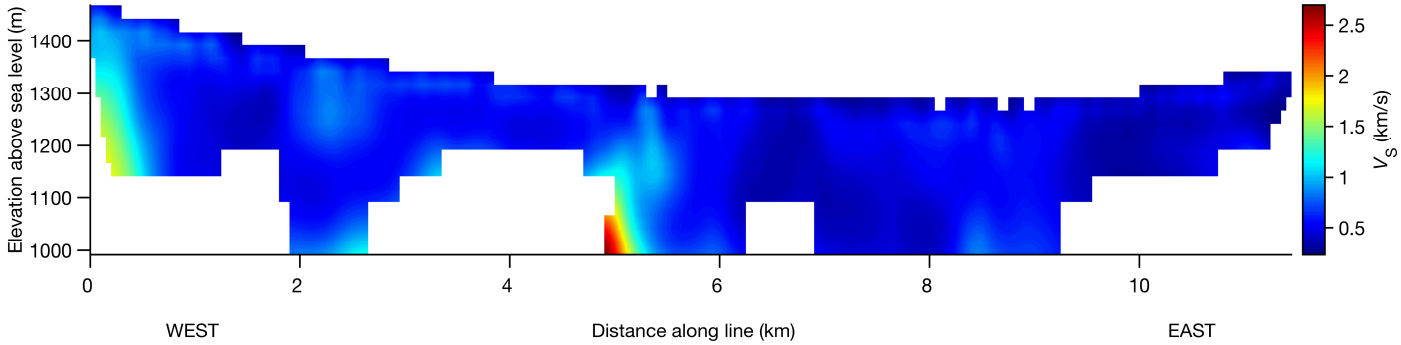
FTAN PMF – 300+ traces

Vs Results -- Rough Version

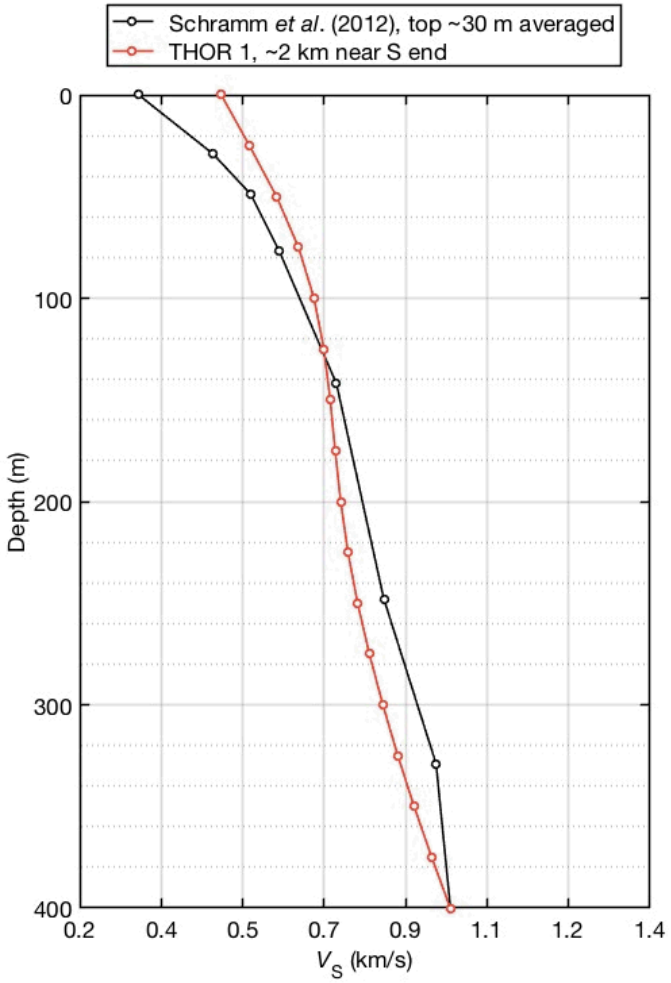
(a)



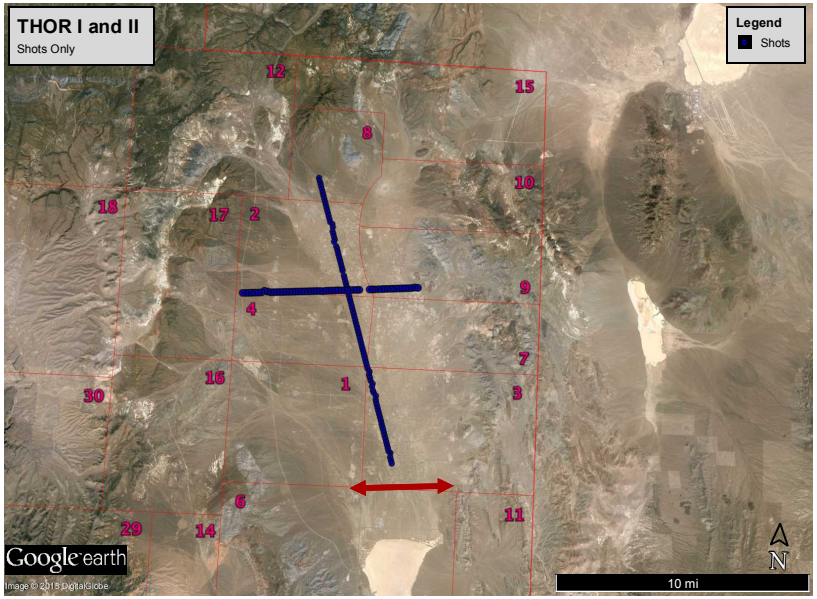
(b)



Vs Comparison to Schramm et. al

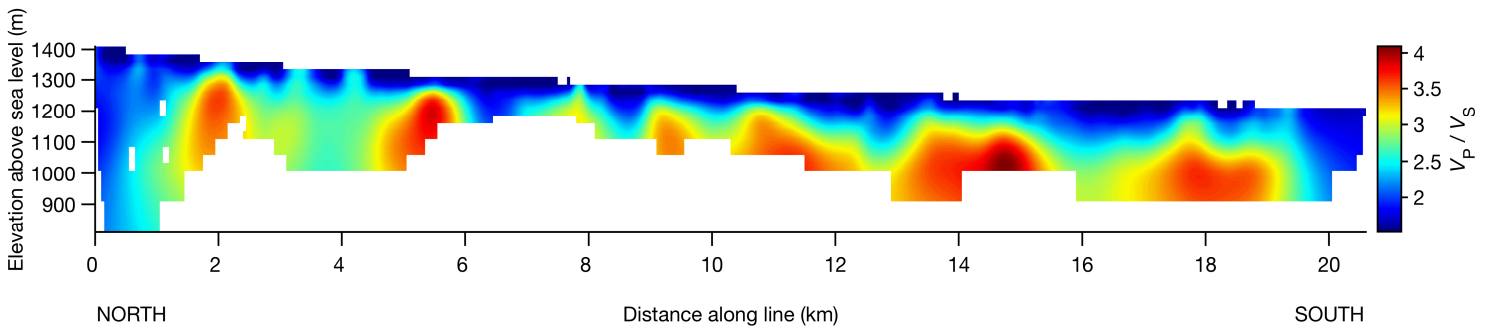


- Schramm Dataset 3 (red arrow), to the south of Thor 1 extent

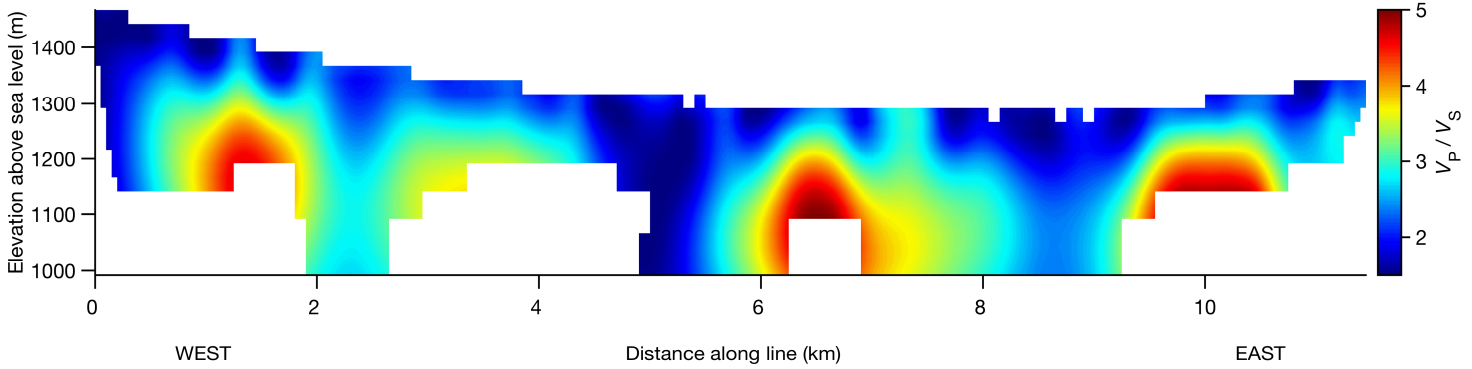


Vp/Vs Results

(a)

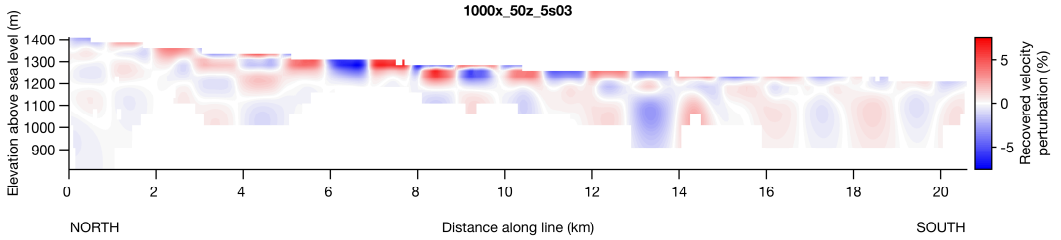


(b)

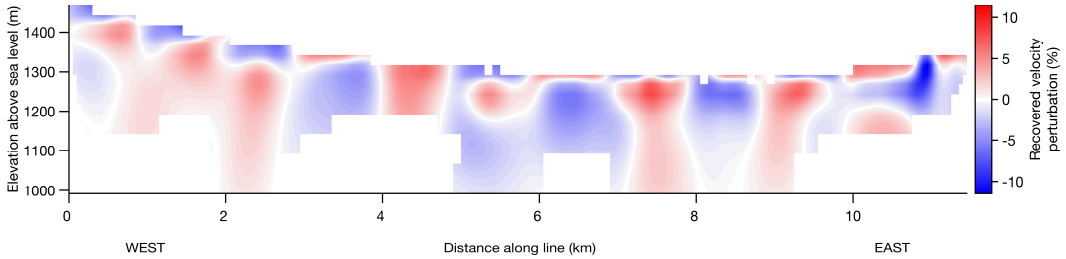


Vp/Vs Checkerboards

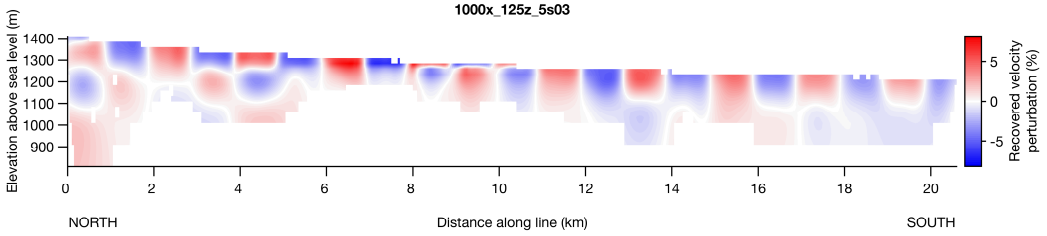
(a)



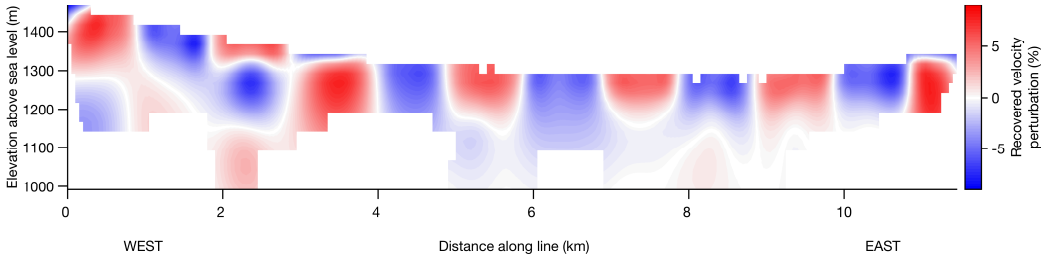
(b)



(a)



(b)

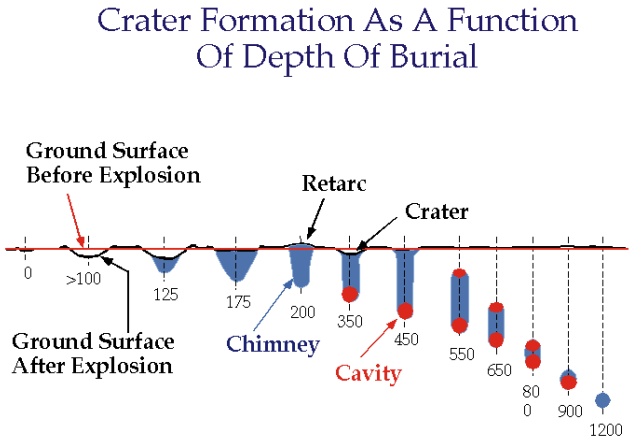


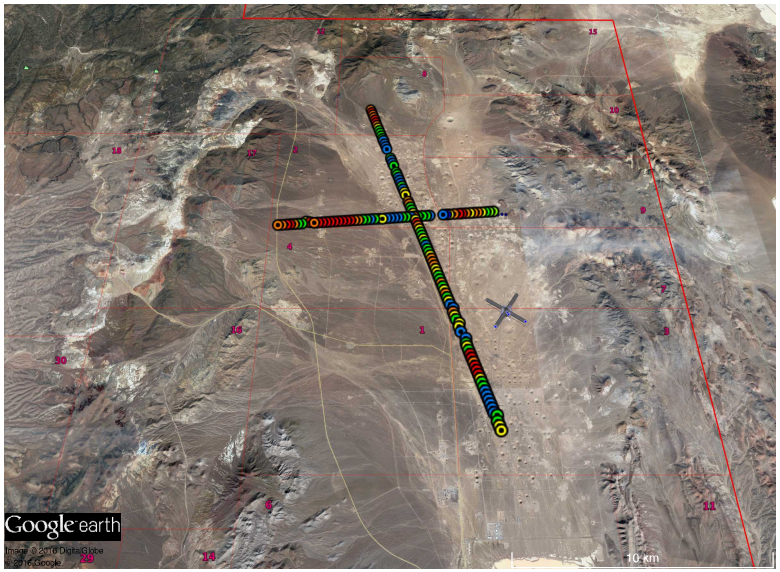
Sandia National Laboratories

PROJECT FREY

Frey: Characterization of a Partially Collapsed Legacy Underground Nuclear Test

- Project Frey is over legacy nuclear test HADDOCK in Southern Yucca Flat
  - 1964 test, DOB 364 m, < 20 kT announced yield
- HADDOCK is unusual as it did not form a surface crater



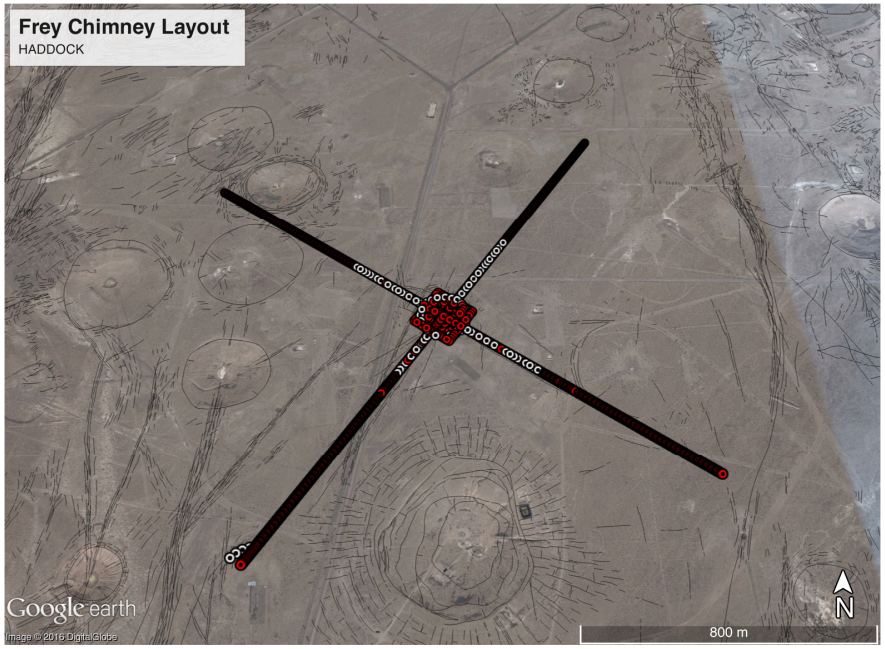


	Thor	Frey
Sensors per shot	~330	~1000
Source Points	144	278
Geographic extent	63 km^2	6 km^2
Geometry	Crossed 2D	Quasi-3D

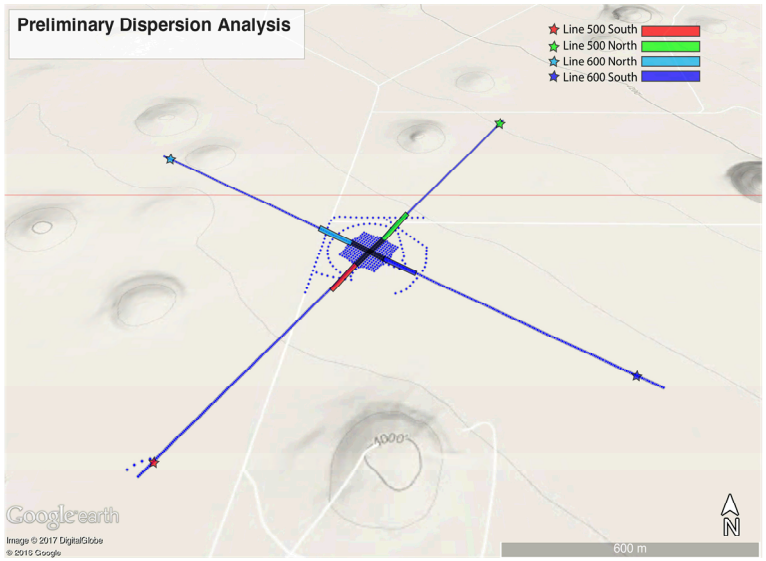
Experimental Plans

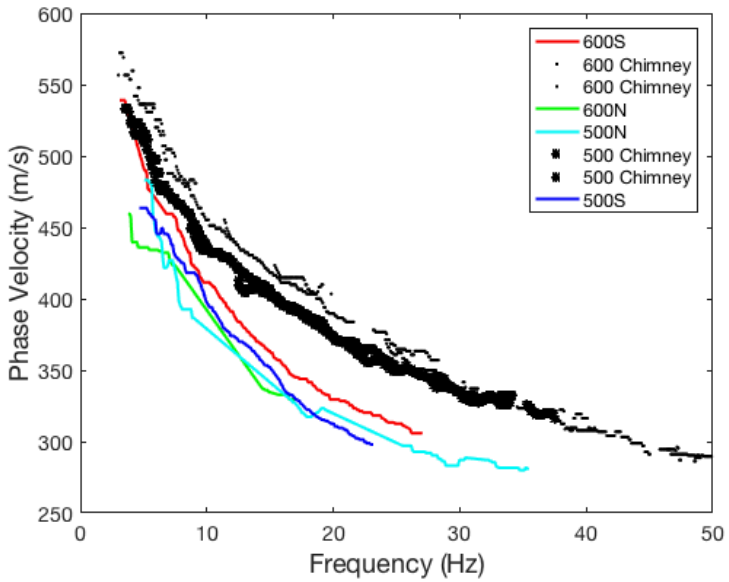
Goal is to isolate a single test (hard to do in Yucca Flat) and understand the effect on seismic wave propagation in support of SPE

- Unlike Thor, seismic reflection processing is planned
- Ray coverage is much denser, with 3D portion
  - 5-meter geophone spacing
  - 15-m source spacing
- Working with University of New Mexico on the reflection processing



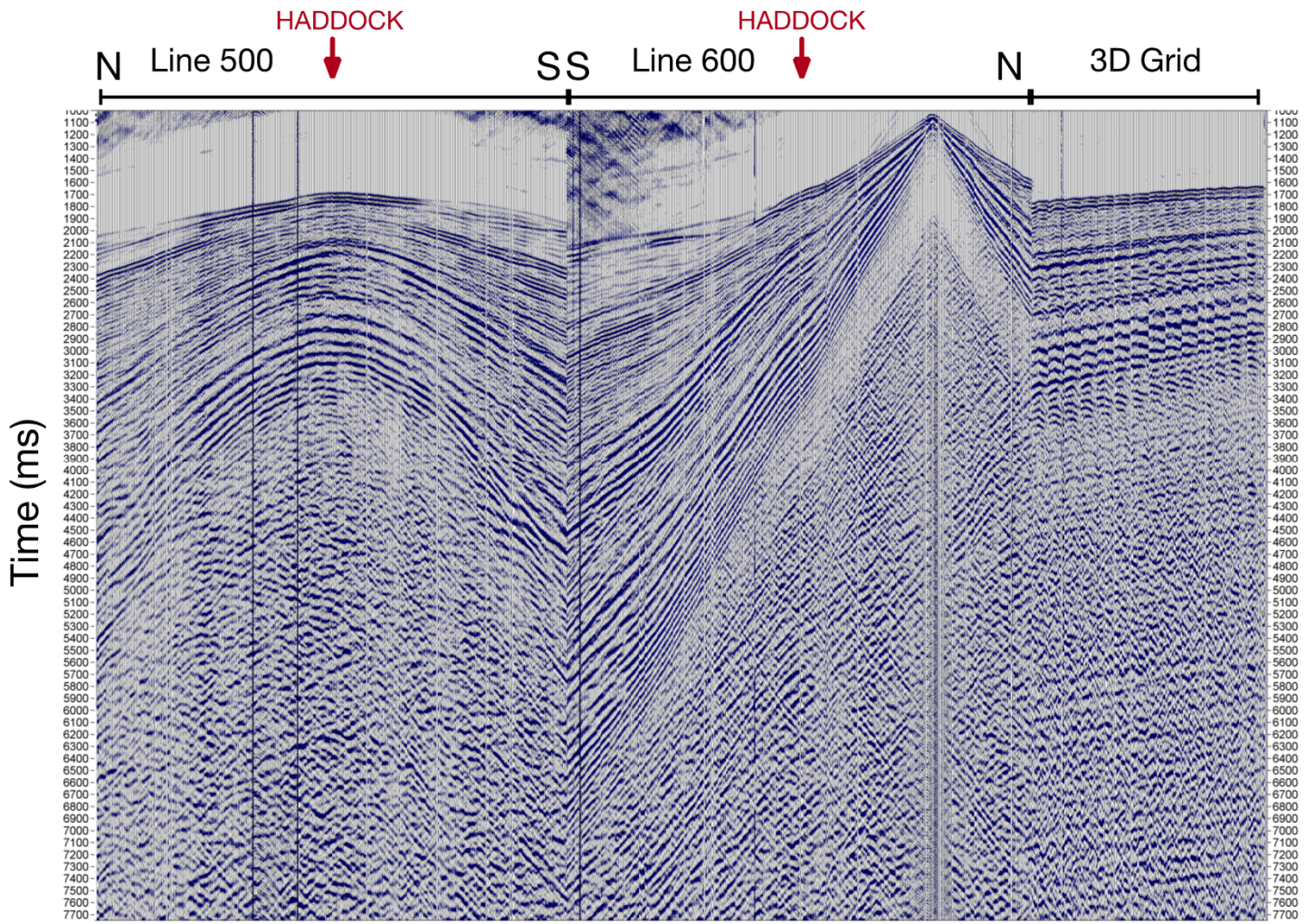
Preliminary Surface Wave results





- Over 500 hits per dispersion curve were stacked to create dispersion curves over the chimney, and immediately adjacent on four sides
- Results clearly show that super-adjacent to chimney are seismically fast (opposite of generally expected)
  - Slapdown causing compaction of alluvium?
  - There seems to be some asymmetry in the chimney

Raw Gather of Frey Data



Acknowledgements

- Students
  - Tori Finlay-Hatton (Kutztown U., IRIS Intern, now UNM)
  - David Tang (University of Texas at Austin)
  - Emily Morton (New Mexico Tech)
  - Matt Perry (now at USGS)
  - Jonah Bartand (U. of Idaho., IRIS Intern)
  - Rebekah Lee (Boise State., IRIS Intern)
  - Liam Toney (Pomona College, IRIS Intern)
- Sandians
  - Leiph Preston
  - Kimberly Schramm (now at USGS)
  - Kristen Phillps-Alonge (now at DTRA)
  - Steve Vigil
- HH Seismic/HK Exploration
  - John Hampshire
  - Rob Hensley
  - Bill O'Donnell
- Desert Research Institute
  - Ping Lee
  - Ray Keegan
- NSTec
  - Jesse Bonner
  - Bob White
  - Frank Spenia