IRIS: USArray Short Course in Bloomington, Indiana
Special focus: Oklahoma Wavefields

A Large N Array at the Nevada National Security Site

R. Mellors¹, C. Snelson², A. Pitarka¹, T. Chen², E. Matzel¹, W. Walter¹ and the SPE team

¹ Lawrence Livermore National Laboratory
² Los Alamos National Laboratory

August 9, 2016

Previously presented at the 2017 Fall AGU
**Source Physics Experiment**

- **Series of chemical explosions at the Nevada National Security Site**
  - Understand S wave generation from explosions
  - Validate modeling capabilities at all scales
  - SPE5: 5000 kg, 76 m, 26 April 2016 20:49 GMT

- **Observations**
  - 10 to 100 m
    - Near-field accelerometers (surface and at depth)
    - High-speed video, photogrammetry
    - EM data
  - 100 to 10,000 m
    - Telemetered seismic array
    - Large-N seismic array
    - Infrasound
  - 10 to 1000 km
    - Regional seismic network

- **Multi-institution collaboration**

- **Data release after two years (IRIS DMC)**
Science goals

Large array goals:
1) Origin of S waves: source or path?
2) Improved structure

Explosion Source Phenomenology

Cross-section of Explosion Source Region
(within 10 - 20 km of the explosion; not to scale)

Conical Volume (shaded) of Extensional Deformation and Tensile Failure

Tectonic Pre-Stress

Spallation

Cracking

Faulting

Shatter Zone

Explosion

P = primary or compressional wave; S = secondary or shear wave; Rg = short-period surface wave

Rock Fabric: Joints Faults

Topography

Tectonic Pre-Stress

Velocity Inhomogeneity

Free Surface

After Patton, LANL

Rock Properties:
P-Velocity
S-Velocity
Density
Qp, Qs
3D model: Geological setting

- Shot point
- 3D velocity model
- Geology and well logs
- Ambient noise
- Added random heterogeneities
- 3D finite difference
- Need to validate and improve!

- Quaternary alluvium
- Tertiary volcanics
- Cretaceous granite
- Paleozoic clastics and carbonates
Large array (996 sensors)

SPE5 5000 kg TNT equivalent at 76 meters

Long-term telemetry stations (radial lines)

Climax Stock (granite)

Weight drop

https://twitter.com/frankklotznnsa

CMG40T (north/east)
Episensor (north/east)
Trillium compact
GS11D (radial/tangential)
3C Large N
Z Large N
weight drop
SPE5

Lawrence Livermore National Laboratory
LLNL-PRES-694105
Instrumentation and logistics

- Equipment and deployment
  - 500 Z (5 Hz DT-SOLO); 500 3C (5Hz Sercel SG-5)
  - Spacing from 25 to 100 m
  - Deployment about 5 days plus QC (crew of 6)
  - 5 week deployment ranging from 300 to 2000 m from shot
  - Contractor: Optim, Inc.

- Data
  - Gain = 1 for shot; then set at 36 db
  - 500 samples/s
  - Continuous recording for interferometry
  - 96% return for shot; 99 % later

- Challenges
  - Shot schedule
  - NNSS rules and regulations
  - Communication between all groups
  - Sensor orientation
QC: Amplitudes and travel times

-Large N
H2 (DT SOLO 3C: 5Hz 80V/m/s)
N = 478

Digitizer clip
2.5 volts

Z (Sercel SG-5 and DT SOLO)

~96% data return for SPE-5; 98% for weight drop
QC: Some waveforms

South (into Yucca Flat alluvium)

dense line (25 m) from north to south

East (along Climax Stock granite)

dense line (25 m) from west to east

Z component; 25 m spacing (SEG polarity)
Structural effects on wave generation

$pS$ converted + source generated $S$ waves

Basin generated $S$ + $Rg$ waves
Wave motion – vertical and tangential
Weight drop
Waveform variation from weight drop

- Considerable azimuthal variation
- Related to geology
Horizontal particle motion (hammer)

<table>
<thead>
<tr>
<th>synthetics</th>
<th>data</th>
</tr>
</thead>
<tbody>
<tr>
<td>3132.0120.syn.H2H1</td>
<td>3132.0120.H2H1.SH47.stack</td>
</tr>
<tr>
<td>3132.0118.syn.H2H1</td>
<td></td>
</tr>
<tr>
<td>3132.0118.H2H1.SH47.stack</td>
<td></td>
</tr>
</tbody>
</table>

EW NS Z

EW NS Z

EW NS Z
Horizontal particle motion (SPE5)

- Horizontal
- 0.25 after P arrival
- 5Hz lowpass
- Sensor orientation:
  - Nominal magnetic N
  - Re-checked in field
  - 80% within 10 degrees
Receiver functions

EW Climax Stock

Data: 1 Hz lowpass (Z)  Receiver function

- Will combine with ambient noise for joint inversion
Conclusions and future plans

- Deployment of approximately 1000 nodes was a success.
- With modern systems, good data recovery (>95%) is expected.
- Rich data include SPE5, hammer source, local, regional and teleseismic data.
- Initial analysis shows clear conversions and scattering.
- Data will be available at IRIS DMC in mid-2018.
Thank you!

The Source Physics Experiments (SPE) would not have been possible without the support of many people from several organizations. The authors wish to express their gratitude to the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development (DNN R&D), and the SPE working group, a multi-institutional and interdisciplinary group of scientists and engineers. This work was done by LLNL under award number DE-AC52-06NA25946.