THE NEVADA NATIONAL SECURITY SITE - SOURCE PHYSICS EXPERIMENT (SPE-N): AN OVERVIEW

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ABSTRACT

The United States' capability to detect underground nuclear explosions under the Comprehensive Nuclear-Test-Ban Treaty (CTBT) requires a clear understanding of explosion phenomenology as it relates to seismic and infrasound signals. Although there has been much progress in modeling these phenomena, this has been primarily based in the empirical realm. The challenge is in utilizing the existing world-wide seismic networks to discriminate among different types of events in near-real to real time. Understanding the changes in seismic energy as it travels from the near-field to the regional to the teleseismic distances is the ultimate goal in monitoring for events of interest. As a result, the logical next step in advancing seismo-acoustic monitoring is to conduct field tests that can expand the predictive capability of the physics-based modeling currently under development.

The Nevada National Security Site - Source Physics Experiment (SPE-N) is the first step in this endeavor to link the empirically based with the physics-based modeling to develop this predictive capability. The current series of tests is being conducted in a granite body called the Climax Stock. This location was chosen for several reasons, including the site's so-called "simple geology" where the granite is a fairly homogeneous body. In addition, there were previous nuclear tests in the same rock body, and the nature of the geology has been well-documented. Among the project goals for the SPE-N are to provide fully coupled seismic energy to the seismic and acoustic seismic arrays so that the transition between the near and far-field data can be modeled, and our scientists can begin to understand how anisotropy affects seismic energy transmission and partitioning. The ultimate goal of the SPE-N project is to develop predictive capability for using seismic energy as a tool for better understanding monitoring issues.

The first shot for SPE-N was conducted in May 2011 as a calibration shot, SPE1, and was composed of 100 kg of chemical explosives set at a depth of 55 m. An array of sensors and diagnostics recorded the shot data, and included accelerometers, geophones, short-period and broadband seismic sensors, Continuous Reflectometry for Radius vs. Time Experiment (CORRTEX), time of arrival (TOA), and velocity of detonation (VOD), as well as infrasound sensors. The three-component accelerometer packages were set at 55 m, 46 m, and 15 m depths in two rings around ground zero (GZ); the inner ring was at 10 m and the outer ring was 20 m from GZ. There were six sets of surface accelerometers (100 and 500 g) in an azimuth of SW from GZ every 10 m. Seven infrasound sensors were placed in an array around the GZ, extending from tens of meters to kilometers. Over 100 seismic stations were positioned in five radials from GZ out to 2 km. Over 400 data channels were recorded for SPE1, and data recovery was about 95% with high signal-to-noise ratio.

Future tests will be conducted in the same shot hole as SPE1. The SPE2 experiment will consist of 1000 kg of chemical explosives shot at 46 m depth utilizing the above-described instrumentation. Subsequent SPE-N shots will be the same size, within the same shot hole, and within the damage zone.

Note: The Source Physics Experiments at the Nevada Nuclear Security Site (SPE-N) in 2011 should not be confused with the 2003 Source Phenomenology Experiments conducted in Arizona (SPE-A) (Yang and Bonner, 2009).

OBJECTIVES

The ability of the United States to detect low-yield nuclear explosions is critical in supporting the CTBT. The current U.S. capability for detecting low-yield nuclear explosions has been primarily empirically based. Thus, the SPE-N is designed to bridge the current predicative capability from empirically based to a physics-based approach. The first series of SPE-N tests is currently taking place in the Climax Stock, a highly fractured granite body. This location was chosen because historic nuclear tests (Pile Driver and Hard Hat) conducted there provide legacy data for a direct comparison to the new data, and also because it was noted during these tests that there were intriguing data that could not be explained at that time (Simmons et al., 2003). In particular, the S-waves seem to be sensitive to the fractures and/or faults within the formation, a phenomenon best studied at the field scale, rather than only on laboratory-scale tests (Antoun, 2010). For these reasons, the Climax site is an ideal location to study the effects of anisotropy in the near-field and wave propagation into the far-field. In addition, the geology of the test bed is well documented, which provides additional constraints in the models. This is a collaborative effort among National Security Technologies, Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), and the Defense Reduction Threat Agency (DTRA).

RESEARCH ACCOMPLISHED

The construction of the SPE-N test bed was started in 2010, with the first test completed in May 2011. GZ is a 91-cm diameter hole, 61 m deep in the granitic rocks of Climax Stock (Figure 1). The GZ borehole intersects two high-angle faults, and core from the hole and image log data show the formation to be highly fractured. There are three high-angle fracture sets, including a conjugate pair, and one low-angle set. In addition, the formation contains perched water that resides within the interconnected fractures. There are six instrument holes, each 20 cm in diameter and 58 m deep, placed in two rings around GZ at lateral distances of 10 m and 20 m. Characterization studies of the test bed include geophysical logs in all holes (density, velocity, image), material properties measurements on core samples from the GZ borehole, and high-resolution seismic refraction/reflection studies.

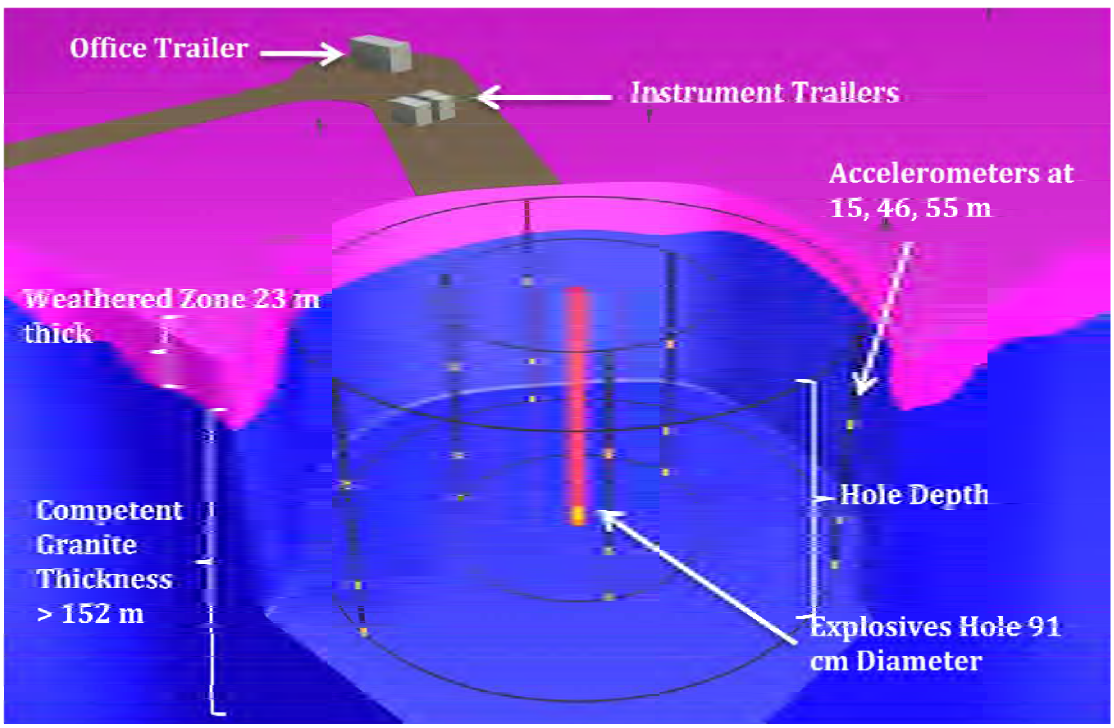

Figure 1. Conceptual drawing of the SPE-N test bed. The red line is the location of GZ and the black lines are the instrument holes. The yellow dots are the accelerometer packages.

To characterize the near-field, the instrument holes contain 3-component accelerometer packages set at 15-, 46-, and 55-m depths, pointing to GZ. The inner and outer rings of instrument holes are offset from each other to maximize azimuthal coverage. Also, for the first test, SPE1, there were two sets of surface accelerometers placed at GZ and every 10 m out to 50 m, inline at an azimuth of WSW with gauges of 100 and 500 g sensitivity. Additionally, CORRTEX, TOA, VOD were installed in the GZ borehole, and RF was acquired in one of the instrument holes. To characterize the far-field, geophones were placed starting at 100 m from GZ and continuing out to 2 km at 100-m station spacing, in five radials around GZ. Broadband, short period, rotational, and infrasound sensors were placed at various locations near GZ and out several tens of km. SPE1 was a very successful calibration shot using 100 kg of SHANFO as the energy source. The SHANFO was loaded into an aluminum canister to simulate a point source, and was placed at a depth of 55 m.

Data recovery was on the order of 95% with over 400 channels recorded, one of the largest data sets acquired on the NNSS to date. Overall, the data quality was high (Figure 2). Data aggregation is largely complete and analysis is underway (see Antoun et al., Mellors et al., Brunish et al., and Patton et al., these Proceedings). The data already show intriguing evidence for the effects of anisotropy radially around GZ.

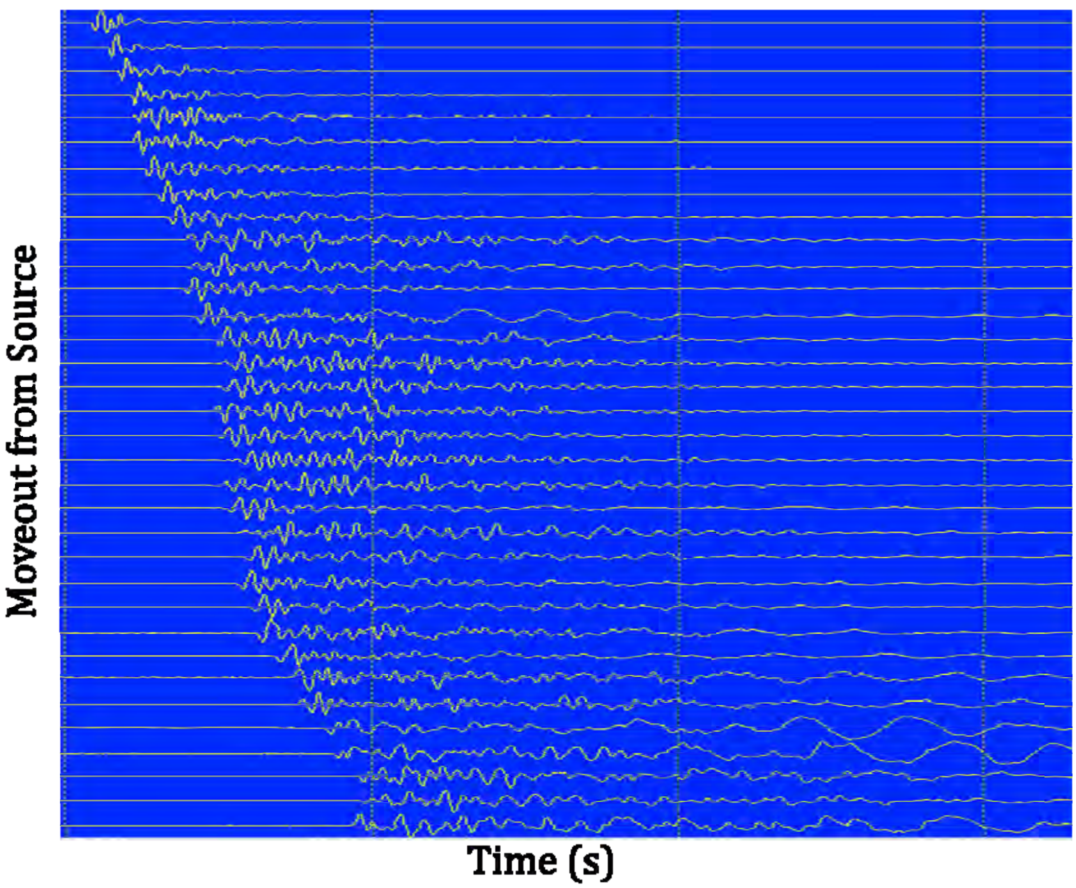

Figure 2. Initial shot gather from one of the radial lines from GZ.

As the data from SPE1 continue to be analyzed, preparations for SPE2 are underway. The same GZ borehole will be used and has been cleaned out to a depth of 47 m, where the next charge canister will be placed. This next test will be 1000 kg of SHANFO, with the centroid of the canister at 46 m. Eight additional tests are planned for this series, with three using the same GZ (Figure 3). SPE3 is planned for the same depth as SPE2, and all subsequent shots will be conducted at successively shallower depths. Eventually, we will reach a point where we will simulate the conditions of a nuclear explosion. Once this GZ has been exhausted, the experiment will move to a new location with a more complicated geology, and the tests will continue. In addition to the seismic, seismo-acoustic, and infrasound studies, additional ground-based and airborne spatial data will be acquired in an effort to further characterize the site.

Yield, kg	DOB m	SDOB m/kt$^{1/3}$	Medium	Comments
0.0025	50	3680	Granite	Empirical Greens function
1.0	50	500	Granite	Simple geology
1.0	30	300	Granite	Same hole as #1
1.0	30	300	Granite	In damage zone of shot #2
1.0	15	150	Granite	Same hole as #1-3
5.0	100	585	Granite	New hole, Over-buried
50	45	122	Granite	Mine from tunnel? Near nominal DOB
1.0	20?	200	Limestone (U16b)	Complex geology
5.0	20?	117	Limestone (U16b)	Nominal DOB?
100?	>55?	TBD	TBD	Rock Valley; see Walter LCP

Figure 3. Chart of the planned SPE-N tests.

CONCLUSIONS AND RECOMMENDATIONS

The SPE-N is a unique opportunity to acquire data at a previously characterized nuclear event site with modern instrumentation and modern modeling capabilities. For the first time, we will be able to model the seismic waveforms in a physics-based model both in the near and far field. In addition, we will be able to couple the near-field into the far-field and see how the waveforms change in this transitional region, thereby providing predictive capability that has not existed previously.

ACKNOWLEDGEMENTS

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