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Site Characterization of the Source Physics Experiment Phase II Location Using Seismic Reflection Data

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Abstract

An objective of the Source Physics Experiment (SPE) is to identify low-yield nuclear explosions from a regional distance. Low-yield nuclear explosions can often be difficult to discriminate among the clutter of natural and man-made explosive events (e.g., earthquakes and mine blasts). The SPE is broken into three phases. Phase I has provided the first of the physics-based data to test the empirical models that have been used to discriminate nuclear events. The Phase I series of tests were placed within a highly fractured granite body. The evolution of the project has led to development of Phase II, to be placed within the opposite end member of geology, an alluvium environment, thereby increasing the database of waveforms to build upon in the discrimination models. Both the granite and alluvium sites have hosted nearby nuclear tests, which provide comparisons for the chemical test data. Phase III of the SPE is yet to be determined.

For Phase II of the experiment, characterization of the location is required to develop the geologic/geophysical models for the execution of the experiment. Criteria for the location are alluvium thickness of approximately 170 m and a water table below 170 m; minimal fracturing would be ideal. A P-wave mini-vibroseis survey was conducted at a potential site in alluvium to map out the subsurface geology. The seismic reflection profile consisted of 168 geophone stations, spaced 5 m apart. The mini-vibe was a 7,000-lb peak-force source, starting 57.5 m off the north end of the profile and ending 57.5 m past the southern-most geophone. The length of the profile was 835 m. The source points were placed every 5 m, equally spaced between geophones to reduce clipping. The vibroseis sweep was from 20 Hz down to 180 Hz over 8 seconds, and four sweeps were stacked at each shot location. The shot gathers show high signal-to-noise ratios with clear first arrivals across the entire spread and the suggestion of some shallow reflectors. The data were processed using Seismic Processing Workshop in a standard reflection processing flow. The results from this vibroseis survey will contribute to the characterization of the location for Phase II of the SPE in order to appropriately execute the experiment.

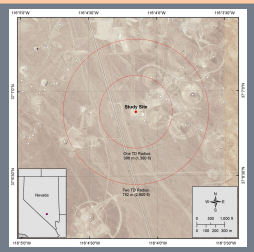

Figure 1: Map of the survey location

Introduction

The Source Physics Experiment (SPE) was designed to improve methods for distinguishing between small seismic events and low-yield nuclear tests, recorded at a regional distance. The SPE utilizes multiple diagnostics, such as seismometers and infrasound, to measure the characteristic behavior of buried explosions, which can then be correlated to determine how a nuclear test would be recognizable from across the globe. In order to obtain an extensive set of data, the SPE is broken up into three phases and each phase is conducted in a different geologic environments. Phase I is taken place in a highly fractured granite body. Phase II will take place in a thick section of alluvium, which has lower seismic velocities due to its lower density. Phase III is yet to be determined.

Before any tests can take place for Phase II, site characterization must be completed to map out the subsurface, determine fault locations and identify any strong variations in medium properties. Our initial characterization effort was a high-resolution vibroseis survey conducted at a potential site, to determine if this hole would be an appropriate fit for the location of Phase II of the SPE. The site has an existing large-diameter borehole that could accommodate the SPE Phase II experiments, and is located in a thick section of alluvium (Figure 1).

Geologic Background

The survey site is located in southern Nevada, in a deep alluvial basin formed by basin-range faulting (Figure 2). The criteria for the Phase II site is alluvium thickness greater than 170 m and a water table deeper than 170 m. Previous drilling showed that the alluvium at the survey site is at least 396 m (depth of the existing borehole), with the top of the underlying volcanic rocks estimated to be approximately 457 m below the ground surface. No water was encountered in the borehole, and the water table in this portion of the basin is estimated to be at the depth of approximately 538 m. The alluvium generally consists of interbedded gravelly sand and sandy gravel. The upper 305 m of alluvium contains clasts of Paleozoic siliciclastic and lesser carbonate rocks, with few clasts of Tertiary volcanic rocks, but borehole geophysical logs indicate increasing amounts of tuffaceous material with depth. The alluvium below 305 m is richer in volcanic clasts than in Paleozoic clasts. Borehole logs also indicate increasing density and water content with depth. North-south trending faults have been mapped in the area, but no faults intersect the borehole. The site is entirely in alluvium, has relatively simple surface geology in comparison to the site for Phase I of the SPE, and the borehole is believed to be fairly stable, making this site a possible candidate for Phase II.

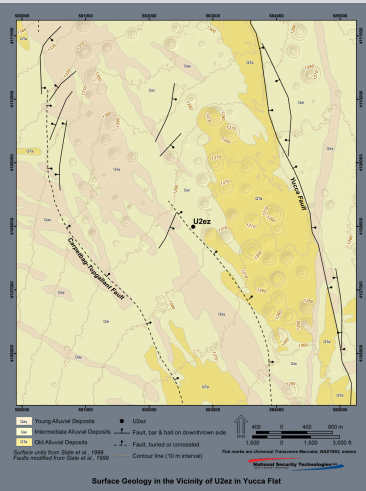

Figure 2: Geologic map of the alluvial basin showing the location of the site relative to nearby faults

Methods

For Phase II of the SPE, we acquired a high-resolution P-wave mini-Vibroseis survey at the potential alluvium site to map out the subsurface geology around the borehole. A trailer mounted vibroseis source with a 7,000-lb peak-force source was used for the survey (Figure 3). When trying to locate faults in a survey, the ideal configuration is to shoot up-dip. However, our access to the site was limited, and for logistical reasons we used an existing dirt road that runs sub-parallel to the traces of the known faults in the area (Figure 1). We used 144 vertical geophones, spaced 5 m apart, with the first geophone the pilot. Shot points were equally spaced between geophones, at 5-m intervals. Shots started at station -12, corresponding to 57.5 m off the north end of the line. After reaching shot point 36, the first 24 geophones were moved to the end of the line, making 168 geophone stations in total. Upon reaching the end of the line, we again continued 57.5 m off the south end of the line, creating a profile length of 835 m. Each gather was made of four stacks of 8-s sweeps with an additional 3 s of listening time and a sample rate of 0.5-ms with a sweep frequency was 20 – 80 Hz (Figures 4 and 5). The SEG-Y reflection data were processed using Seismic Processing Workshop (SPW) to image sub-surface reflectors (Figure 6).

Figure 3: UNLV Mini-Vibe Source

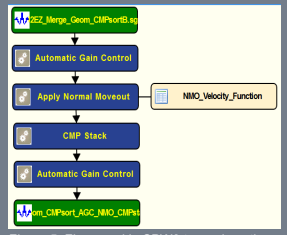

Figure 5: Flow used in SPW3 to produce the final CMP stack

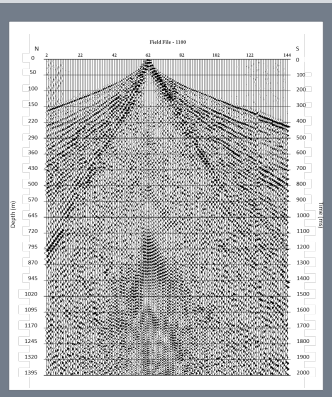

Figure 4: Shot gather

Conclusion

The results from this seismic reflection survey indicate a reflecting surface at a depth between 220 and 280 m (Figure 6). Lithologic logs from holes in this area indicate a change in alluvium composition at a depth of approximately 305 m, with the overlying layer containing more Paleozoic rocks than volcanic rocks and the underlying rock containing less Paleozoic rocks and more volcanic rocks. Therefore, the reflector found in this survey appears to correspond to an increase in seismic velocity associated with an increase in volcanic clasts in the alluvium. The identification of this boundary will be used to inform future modeling efforts to distinguish a weaker interface that may be associated with spalling of the surface when the new experiments begin. To further delineate this boundary migration could be used to obtain the true depth and dip of the reflector.

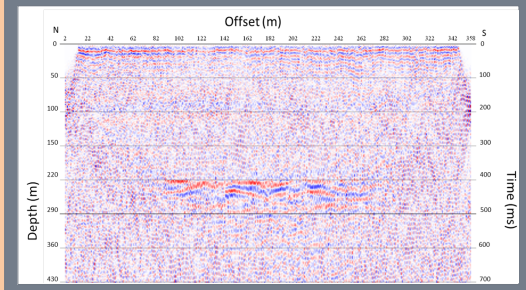

Figure 6: Seismic reflection stack across the survey location

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