ASSESSMENT OF REGIONAL EXPLOSION DISCRIMINANTS USING DATASETS OF UNPARALLELED SPATIAL SAMPLING: THE BIG HORNS ARRAY SEISMIC EXPERIMENT (BASE)

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ABSTRACT

Discrimination of regional earthquakes, single-fired explosions, and delay-fired mining explosions is dependent upon separation of path and source. Waveforms of regional events are typically sparsely sampled in space, with individual observations being separated by hundreds of kilometers, thus complicating the process of separating source and path effects. In this work, we are taking advantage of data being collected for the Big Horns Array Seismic Experiment (BASE), an EarthScope project funded by the National Science Foundation (NSF), to investigate the degree of spatial sampling of the seismic wavefield needed to characterize three-dimensional (3D) wave propagation effects in a complex regional setting and the implications for regional discrimination. BASE consists of a hybrid active/passive short-term seismic deployment that greatly increases the spatial sampling of the seismic wavefield in north-central Wyoming, a region with abundant natural and man-made events. Our goal is to fully assess the performance of regional seismic discriminants as they are applied to earthquakes, contained single-fired explosions, delay-fired mining explosions, and mining collapses using the unprecedented spatial sampling presented by the BASE dataset.

The centerpiece of USArray, one component of the NSF-sponsored EarthScope program, is the Transportable Array (TA) a rolling 70 km grid of over 400 broadband seismic stations that is already producing more densely sampled wavefields. BASE is designed to embed seismic instrumentation from the Flexible Array (FA) within the TA in order to construct complete 3D structural models of the region around the Big Horn Mountains, in conjunction with known geologic structures. The deployment, which is occurring in three phases that began in the summer of 2009 and will continue into the fall of 2010, has five main components. The first is a ca. year-long deployment of 39 broadband systems to infill the TA in the vicinity of the Big Horn Mountains to achieve an average spacing of 35 km. The second is an array of 170 short-period instruments that are being deployed along a grid of five lines with a station spacing of 5 to 10 km. The third component consists of three 5-element regional seismic arrays that are being deployed to assess the role of arrays in signal detection and characterization for discrimination purposes. These arrays will in place for 6 months, beginning in May. In July 2010, an active-source seismic experiment consisting of two profiles with 1850 “Texan” seismographs deployed at 0.1 to 0.5 km and up to 20 large (500–2000 lb) single-fired shots are being conducted. The seismic signals from the shots will also be recorded by the passive arrays. Finally, 850 Texan seismographs will be deployed for two weeks along the short-period grid in passive mode to achieve a nominal station spacing of 1 km.

Analysis plans include calculation of two-dimensional (2D) and 3D velocity models of the crust and upper mantle and a 2D amplitude tomography. The resulting Q models will be used to estimate amplitude corrections that will be applied to the observational data prior to the discrimination analysis. Results from this study will allow us to quantify the degree of regionalization and instrumentation necessary for successful discrimination in a tectonically complex region. This result will provide a basis for assessing regional discrimination performance in areas with substantially reduced datasets.

OBJECTIVES

The primary objective of the work being performed under this contract is to quantify the degree of regionalization and instrumentation necessary for successful discrimination in a tectonically complex region. Ultimately, this result will provide a basis for assessing regional discrimination performance in areas with substantially reduced datasets. To date, our work is entirely focused on collecting a large and diverse seismic dataset in north-central Wyoming, during a field season that stretches from May to October 2010.

The work for this contract piggybacks on a project sponsored by the EarthScope program of the NSF, known as BASE—the Big Horns Array Seismic Experiment. The focus of the NSF proposal is on imaging the deep structure of basement-cored arches in order to understand the mechanisms of formation of the Rocky Mountains. Other science goals of the NSF project center on the nature of faults at depth in the crust and on questions about crustal rheology. In addition to producing velocity models of the crust and upper mantle, the seismic-imaging experiment will determine whether faults continue as sharp features at depth or whether they spread into a broader zone of ductile deformation.

RESEARCH ACCOMPLISHED

At the time of the submission deadline for the meeting proceedings, the fieldwork for this contract was in full gear. Thus, this paper focuses primarily on the nature of the field experiment.

BASE is designed to embed seismic instrumentation from the EarthScope FA within the EarthScope TA in order to construct complete 3D structural models of the region around the Big Horn Mountains of Wyoming, in conjunction with known geologic structures. The TA is a rolling 70-km grid of over 400 broadband seismic stations that is the centerpiece of the USArray component of the NSF-sponsored EarthScope program. The TA is deployed in north-central Wyoming and southern Montana until early fall of 2010. The BASE deployment of FA instruments, consists of three phases that began in the summer of 2009 and that continues into the fall of 2010. The deployment can be divided into five components described below and illustrated in Figure 1.

The first component is a ca. year-long deployment of broadband stations designed to infill the TA in the vicinity of the Big Horn Mountains to achieve an average spacing of 35 km. Installation of these stations, using CMG-3T broadband seismometers, took place during the summer and fall of 2009; 39 CMG-3T broadband seismometers were installed in the Big Horn region. Of these, 27 stations were placed in locations that densify the grid of transportable array stations in the area. Another 12 were placed on transect lines (Figure 1). The broadband stations all have Quanterra Q330 data loggers sampling at 50 Hz. Stations were oriented using an Octans, a high-precision fiber-optic gyrocompass. These stations will remain in place until fall 2010.

The second component consists of 170 short-period seismometers deployed along five transects at 4 to10 km spacing, as well as three mini-arrays at the ends and in the middle of the main E-W transect (line M, Figure 1). Seventy short-period seismometers were deployed in April, 35 in May, and the remaining sites in June.

In July 2010, an active-source seismic experiment, the third component, will be conducted (Figure 1). This effort will consist of 1850 “Texan” seismographs deployed along one E-W and one NW-SE transect. Seismometer spacing will range from 0.1 to 0.5 km. Twenty large (500–2000 lb) single-fired explosions will be recorded along the active source lines. The shots will also be recorded by the broadband and short-period arrays.

Following the active source experiment, the Texan seismometers will be redeployed in passive source mode along the five transects shown in Figure 1. Station spacing is 1 km. Eight hundred fifty Texans will be deployed in passive mode for two weeks (instrument/battery swaps every 4–5 days). The single-fired shots at mines will be fired into this array.

A day’s worth of recording at a TA station near Big Horn, Wyoming (Figure 2), demonstrates the nature of the data that will be collected at each seismometer site. Recordings of teleseisms, regional earthquakes, and mine blasts are expected to be common. This will provide a rich dataset for discrimination analysis.

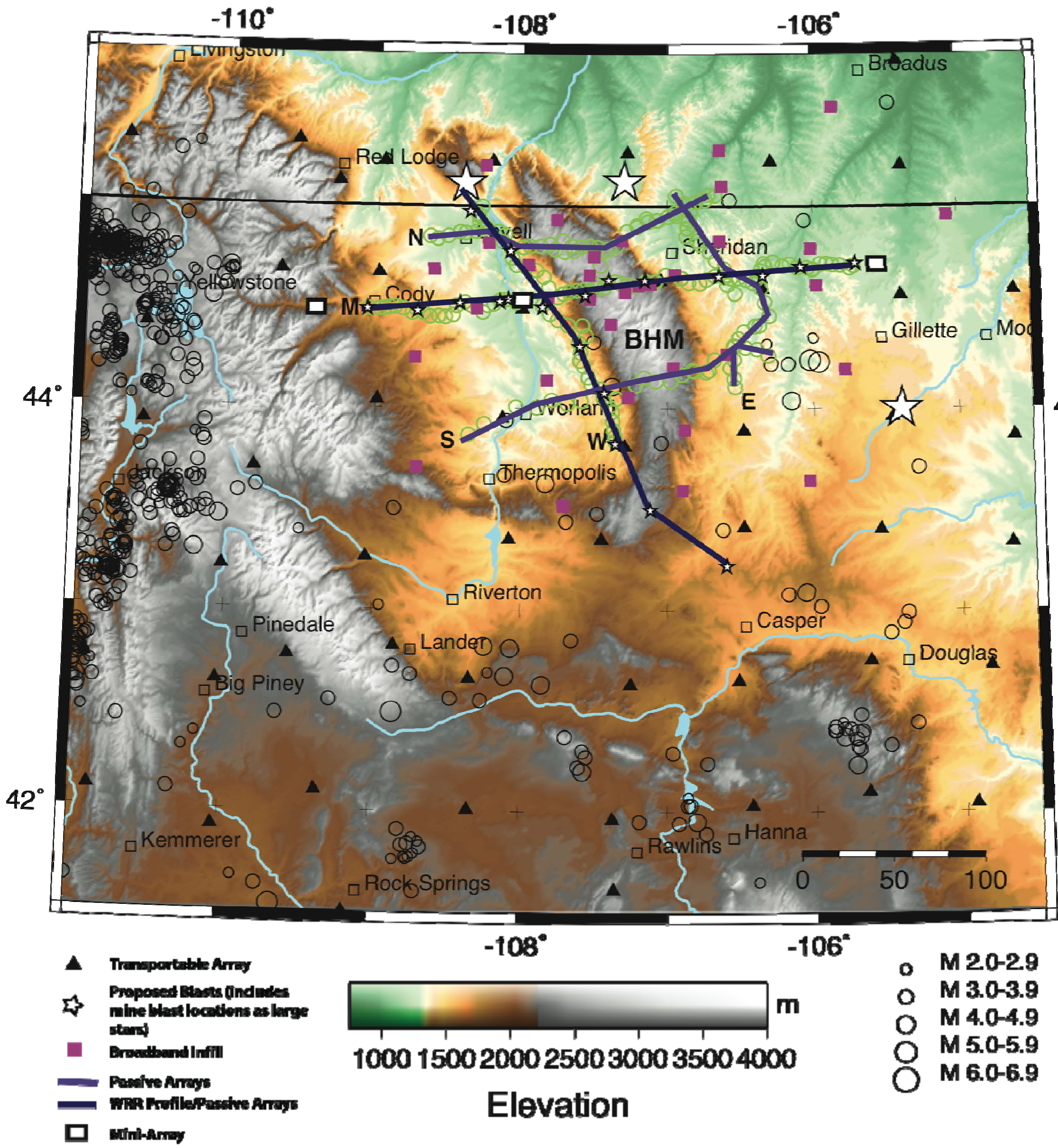

Figure 1. Topographic map of north-central Montana showing seismic experiment geometry and regional seismicity. A total of 27 broadband stations (pink squares) infills the EarthScope TA stations (black triangles). A total of 182 temporary stations (green circles), including 12 with broadband sensors, are deployed along the five array lines at 4- to 10-km intervals. Three mini-arrays are located along the central transect. Single-fired shots (small white stars) are to be fired into 1850 Texans deployed along transects with shots. Subsequently, 850 Texans will be deployed along all transects for 2 weeks, to record passively and infill the array lines to a station spacing of 1 km.

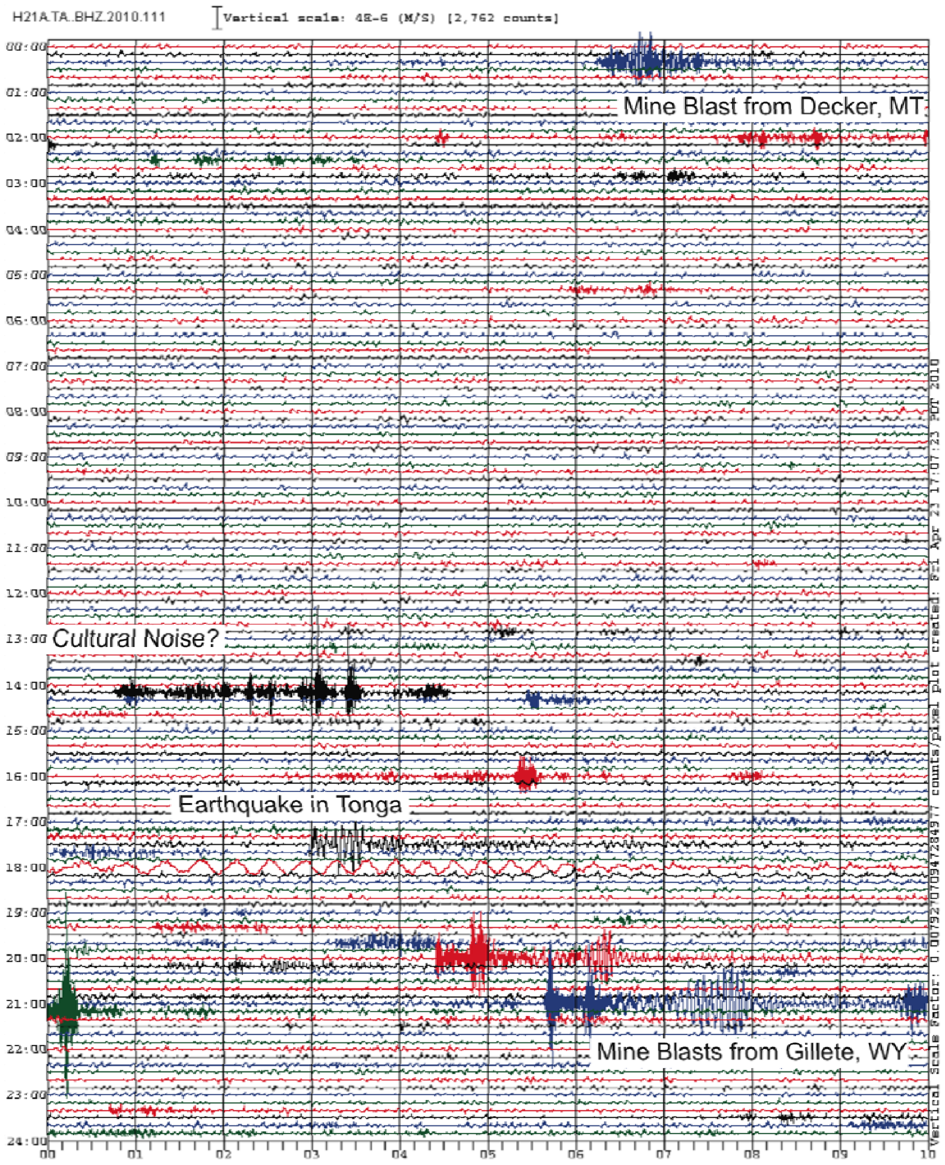

Figure 2. Typical day of seismicity recorded at a TA station at Big Horn, Wyoming. Each line displays 10 minutes of ground motion.

CONCLUSIONS AND RECOMMENDATIONS

As the field work for this project is just underway, it is still too early to draw any detailed conclusions. Analysis plans for the dataset include calculation of 2D and 3D velocity models of the crust and upper mantle and a 2D amplitude tomography. The resulting Q models will be used to estimate amplitude corrections that will be applied to the observational data prior to the discrimination analysis. These detailed regional models, combined with the dense spatial sampling of BASE, will put us in an excellent position to be able to quantify the degree of regionalization and instrumentation necessary for successful discrimination in a tectonically complex region.

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