Seismic Field Test
SureWave Technology at Federal #2 Mine
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Dr. Keith A. Heasley
Professor – Mining Engineering
West Virginia University
Morgantown, WV

Introduction

One of the critical steps for a successful mine rescue operation is the fast and accurate determination of the location of trapped miners. If the communication/tracking system of an underground mine is severely damaged in a mine accident or explosion, geophysical methods could be the only available tools for locating the trapped miners. Among the geophysical methods that might be employed for this purpose, the seismic method appears to be the most promising practical tool since it inherently has good distance capabilities, can be designed to be simple, fast and easy to use, and is reasonably priced. In recognition of this fact, the WV Mine Safety Technology Task Force (May 29, 2006) recommended that four mine rescue seismic systems (and appropriately qualified personnel) be positioned throughout the state for rapid deployment in case of an emergency.

The Department of Mining Engineering at West Virginia University had been tasked in 2006 with assisting the state Office of Miner's Safety Health and Training to: 1) conduct field test of the seismic locating system at underground coal mines to determine the seismic system's operating capabilities and limitations under various geological and mining conditions, and 2) help determine the exact specifications of the required seismic system that will fill the needs for establishing a practical mine-rescue seismic capability in the state of West Virginia. In that earlier work, a number of different micro-seismic systems/manufacturers were evaluated.

All of these original systems used geophones to detect ground vibrations from miners pounding on roof of the mine, and all of the original systems required that the seismic signal from the miners' pounding be "larger" than the background seismic noise in order to detect and locate the signal. In field tests with these original systems, the signal from miner's pounding was successfully detected (and located) from a coal mine that was 440 ft deep (Heasley et al., 2006), but was not detected at a coal mine that was 780 ft deep (Heasley et al., 2007), apparently because the pounding signal was not above the background noise. At that time, it was suggested the some type of filtering to clean up the signals and better accentuate the pounding needed to be investigated to make the present geophone systems more feasible at increased depths.

Recently, the SureWave Technology company from the United Kingdom approached the Mining Engineering Department at West Virginia University with a micro-seismic system that they were fairly sure would be able to detect the miner's pounding signals at depths up to 2000 ft. The SureWave system uses an advanced proprietary signal processing system to greatly enhance the signal-to-noise ratio for detecting rock noises and miner pounding. In order to evaluate the practical application of their system, a test was arranged at the deeper of the two mine sites from the previous seismic testing

The SureWave System

The minimal SureWave system consists of 2 tri-axial sensors, power packs and a main processing unit. The whole set of equipment is portable and can be deployed rapidly. The system complete with 2 x 225 ft cables, 2 sensors, battery packs and main processing unit with touch screen display weights less than 60 Kg (135 lbs). For installation, the sensors are "located" on the ground, the cables are connected between the sensors and the processing unit, and the processing unit is connected to the battery packs. The tri-axial sensor is designed in a rugged steel case, and should be installed in competent ground in order to get optimal contact with the ground vibrations. Also, the sensor needs to be installed as level as possible (using a bubble level on the top of the case), and oriented in a known horizontal direction, to allow accurate location analysis of the detected signal.

In normal operation, the system is started to commence recording ground vibrations. When an event of "interest" occurs, the system triggers and captures the event, and then proceeds to analyze the location of the event.

Field Test Site

The field test documented in this report was performed at the Federal #2 Mine on Wednesday, February 23rd, 2011. This mine is located along Miracle Run road in Fairview, West Virginia, approximately 23 miles from Exit #155 of interstate 79, to the West of Morgantown, West Virginia (see Figure 1). At this mine, two sites had been established for testing the previous seismic systems. Surface site #1 for the seismic test was located next to a sediment pond for the mines refuse disposal areas (see Figure 2). At this location, the overburden is 779 ft thick and the primary surface location is centered over an intersection on the underlying track (see Figure 3). Site #2 was located at the top of a nearby hill (see Figure 2) at over 1000 ft of overburden. This site with the valley and the nearby hill provided a good opportunity to investigate the seismic system performance at two different depths (with the same geology).

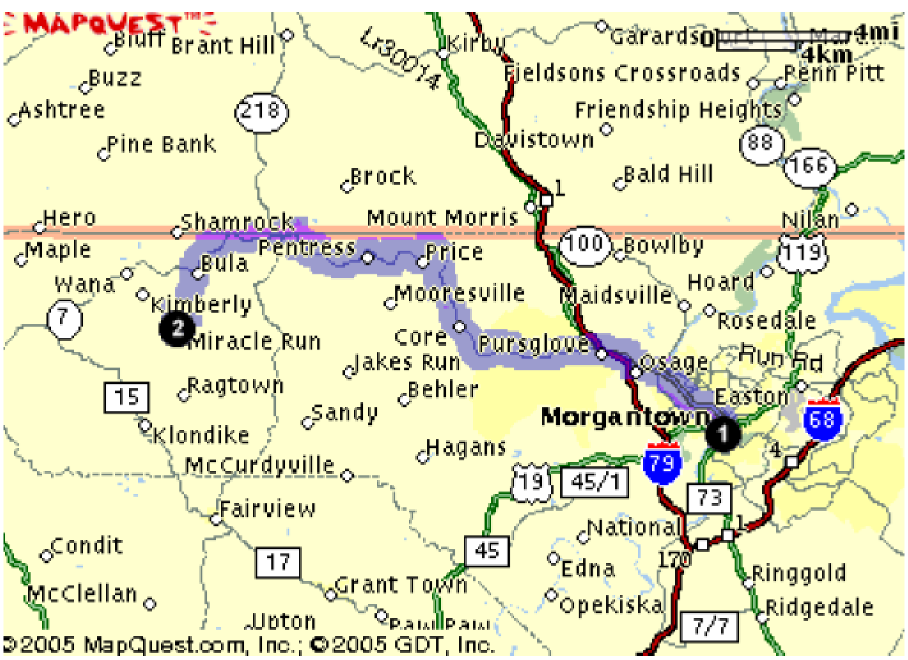

Figure 1. Location map for Federal #2 Mine.

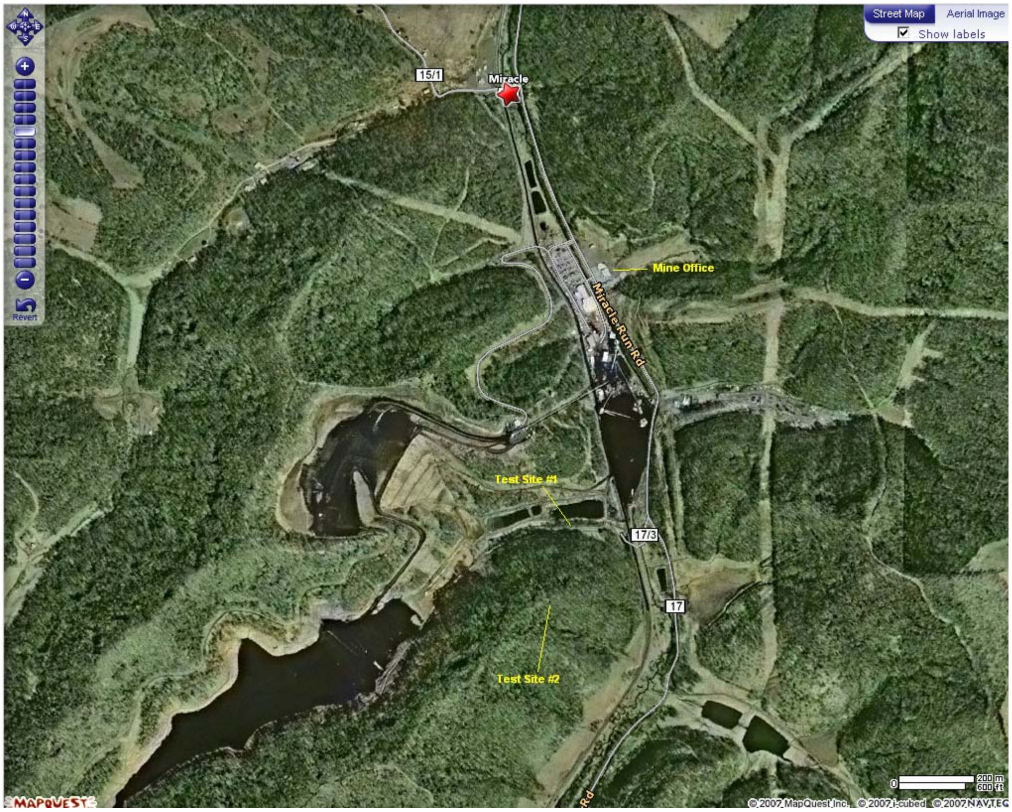

Figure 2. Aerial view of the mine and the two seismic test sites.

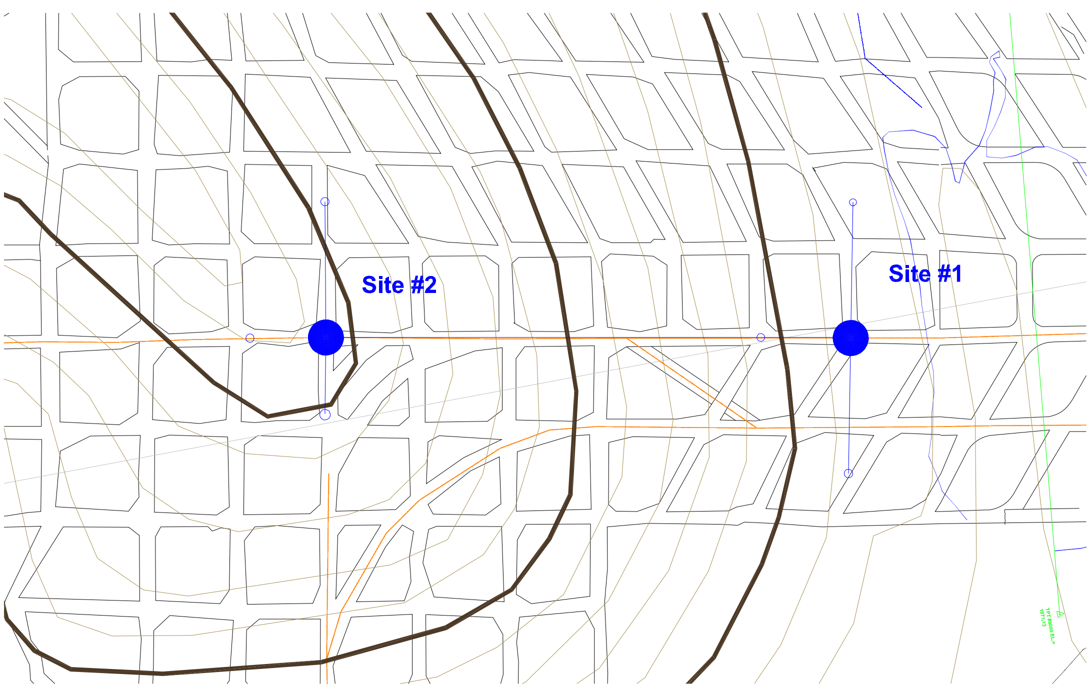

Figure 3. Mine map under the surface test sites.

Sensor Installation at Site #1

Originally, it was intended to have 2 sensors with the system at the field test site to facilitate location analysis; however, the second sensor with the system was misplaced during the shipping process. Therefore, the tests at this file site were only performed with one tri-axial sensor, and the results do not include any location analysis. With only one sensor at the site, it was installed at the center of Site #1 as shown in Figure 3. The sensor itself was dug into the surface soil about 2 ft as shown in Figure 5, and the main processing unit was connected to the sensors and batteries as shown in Figure 6. This sensor location is exactly 779 feet above the mine and directly over the signaling location (entry 5, crosscut 21) underground.

Figure 4. Photograph of surface sensor installation.

Figure 5. Photograph of the main processing unit, cabling and batteries.

Personnel

For the test, there was both a surface team and an underground team. The surface team installed the seismic system at the surface test area and recorded the signals from underground. The underground team traveled underground to entry #5, crosscut #21 and performed the pounding cycles.

The **underground team** consisted of:

- Matt Bonnell - Mine Representative
- Morgan Sears – Graduate Research Assistant, WVU

The **surface team** consisted of:

- Edward Hoy – Mine Represeantative
- Philip Shaw – Managing Director, SureWave Technology
- David Manning – Director, SureWave Technology
- Dr. Keith Heasley – Professor of Mining Engineering, WVU
- Ihsan Berk Tulu – Graduate Research Assistant, WVU

Underground Test Protocol

For the underground signaling, the best technique from the previous testing was used, a crib block pounding on the roof rock. For the roof pounding, the "trapped miner" pounded 5 times in rapid succession (approximately 1 to 1.5 seconds apart) at the beginning each minute for 5 minutes (5 sets). During the signaling, the exact time (within a few seconds) that the pounding started was synchronized with the surface team. At one point, in order to double check the signal acquisition, both miners underground alternated roof pounding to double the frequency.

Results

Seismic data from the sensor was digitized and collected on the processing unit for display. Initially, without special signal processing to remove the background noise, the typical ground signal looked like Figure 6. In this figure, the X-axis is in milliseconds, and the Y-axis is the unprocessed bit count from the signal (which is proportional to ground particle velocity). Notice that the background noise is reaching about 2×10^5. After the system was configured into its normal mode of removing and 'seeing through' the site generated background noise, the signal from the miners pounding was clearly recognizable as shown in Figure 7. Notice that the background noise is now about 2×10^3 and has been reduced by a factor of about 100, and the resulting processed signal-to-noise ratio is about 4 to 1. The SureWave equipment detected all of the miner's pounding, including the double frequency check.

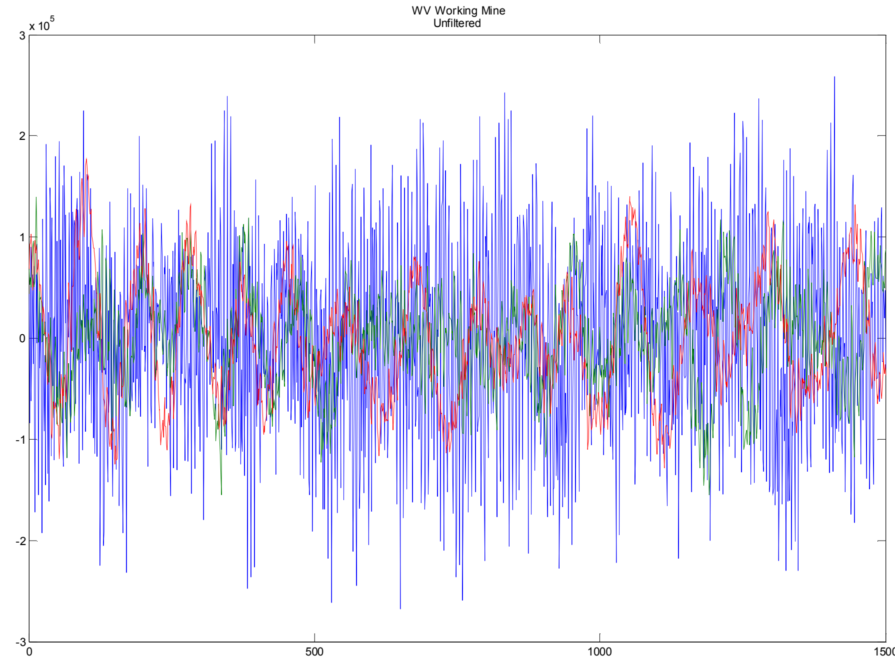

Figure 6. Unprocessed background noise.

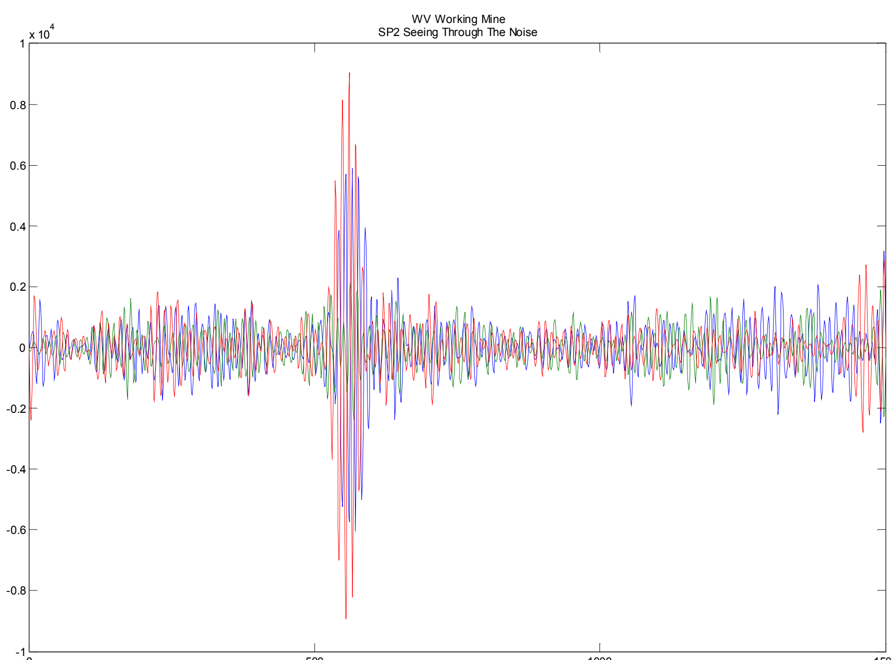

Figure 7. Processed signal showing the miner pounding.

Previously at this site, the "traditional" mine micro-seismic equipment was not able to detect any signal above the background noise. In particular, it was noted that the background noise environment at the site was highly complex and unusually strong. We could hear the bulldozer working on the coal stockpile not too far away. Also, the coal cars used for mine's bunker system were not too far away underground (2000'). Any of these sources and other unknown sources could have been interfering with the detection of the pounding signals.

Site #2

Later that same day, the equipment was moved to Site # 2 at the top of the hill at over 1000 ft of overburden. At this location, additional testing was done and the equipment performed with the same quality of signal detection as previously shown for Site #1.

Future Work

In the future, we hope to test this equipment at depths up to 2000 ft and to investigate the effect of horizontal offset distances on signal detection and to investigate the location accuracy of the equipment. Also, SureWave has plans for an enhanced sensor that can be evaluated.

Acknowledgements

We would like to acknowledge Patriot's Federal #2 Mine for the access to their mine and surface site and for the technical assistance in preparing for and performing this seismic test. Second, we would like to thank SureWave Technology for providing the seismic equipment and personnel to record the seismic data and for assisting in interpretation and analysis of the data.

References

Heasley, Keith A., Yi Luo and Monte Hieb, 2007, "Seismic Field Test at Federal No. 2 Mine", project report, West Virginia University, 7 p.

Heasley, Keith A., Yi Luo and Monte Hieb, 2006, "Seismic Field Test at 4 West Mine", project report, West Virginia University, 8 p.