

# **Seismic Field Test Preliminary Report - 9/30/06**

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## **Background**

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 has been tasked 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. This document is a report on the preliminary findings from a seismic field test conducted on September 30<sup>th</sup>, 2006. During this test we collected a considerable amount of seismic data that we will be analyzing in the future. After this data is thoroughly analyzed in the future, we will be producing a thorough final report.

## **Field Test Site**

As part of the project to develop a seismic location system for trapped coal miners, a field test was performed at the 4 West Mine of the Dana Mining Co. of PA, Inc. on Saturday, September 30<sup>th</sup>, 2006. The 4 West Mine is located a few miles from the Mt. Morris Exit (Exit

#1) off of interstate 79, just North of Morgantown, West Virginia and the Pennsylvania border (see Figure 1). The 4 West Mine is presently operating one continuous miner section which is driving an eleven entry main in a southwestern direction. The exact location for the test was chosen near the top of a local ridge in order to get the maximum amount of overburden and directly above the haulage entry in the mine for the ease of access (see Figure 2). The surface cover at the site was a hay field which allowed very easy access to install the seismic system.

On the surface, six geophones (4 surface and 2 tri-axial downhole) were arranged in a “T” pattern (see Figure 3). The four surface geophones were simply buried under one shovel full of the soil. They were oriented flat with their “y” axis pointing in an inby direction (2418). The two downhole geophones were placed vertically in shallow (3 ft deep) auger holes. These downhole geophones were wedge into the hole with a crowbar and then buried with soil that was lightly tamped. Their horizontal orientation was not set. (The sub-soil consisted of hard brown clay which was fairly difficult to auger. The exact total thickness of this soil is not presently known.)

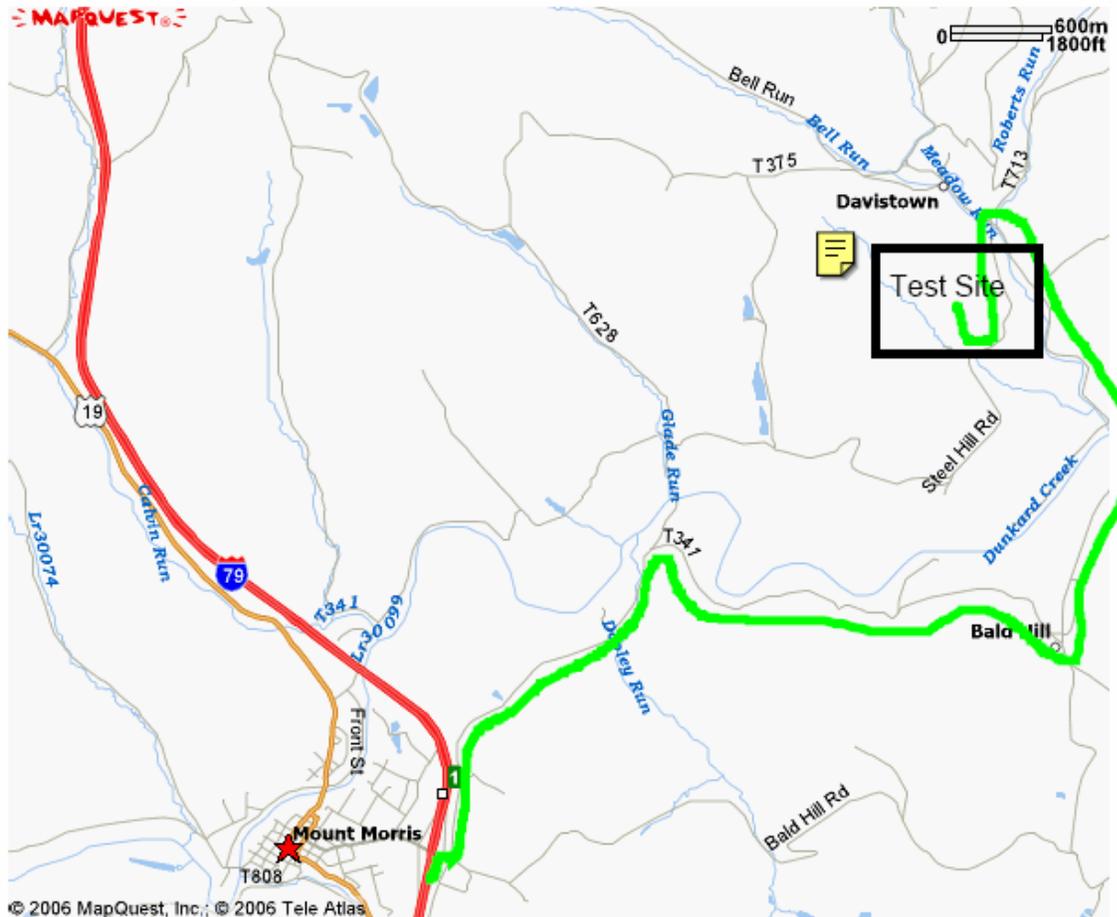
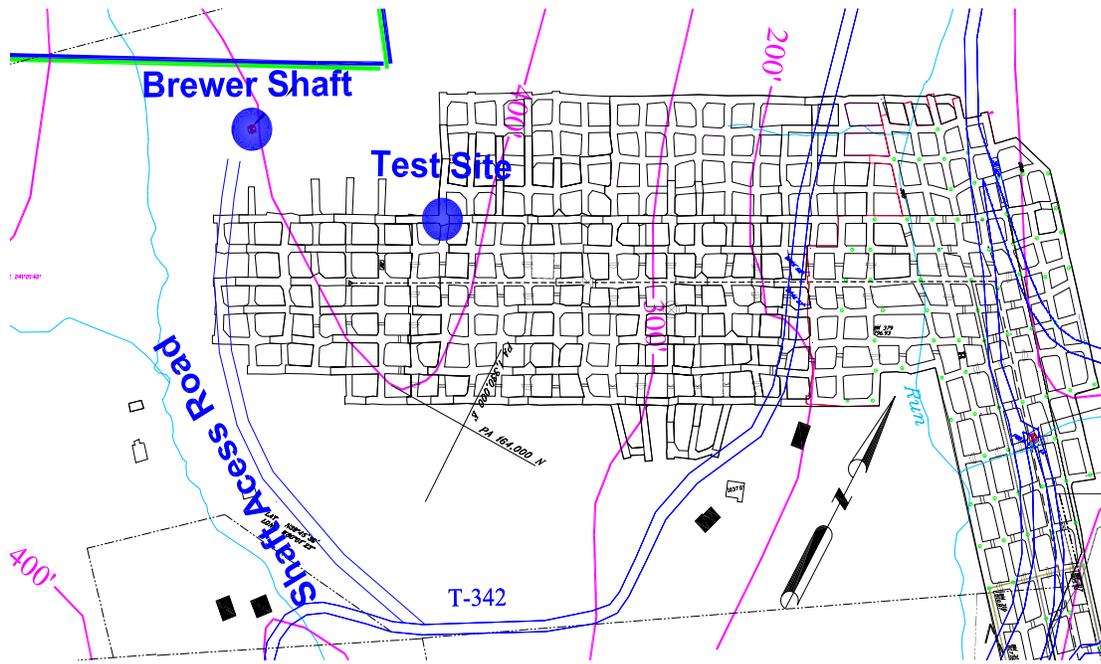


Figure 1. Location Map of Seismic Test Site.



**Figure 2. Location of the Seismic Test Site.**

**Figure 3. Location of the Surface Geophones and Underground Pounding Sites.**

The four surface geophones (#1-#4) were installed at locations 1-4, respectively, as shown in Figure 3. Geophone #5 was a downhole design that was installed at location 1, and similarly, Geophone #6 (also a downhole design) was installed at location 2. The depth of cover at location #2 was surveyed at 441 feet. Geophone location 2 is the center of the “T” and is located directly over entry #7, crosscut #18 where the first underground signaling occurred. Subsequent

underground signaling was performed at: entry #7, crosscut #17 (under geophone location 3); entry #7, crosscut #16; and entry #7, crosscut #15 (see Table 1).

Table 1. Location of the Geophones and Underground Signaling Sites

### Coordinates

Survey Point	X	Y	Surface Elevation	Geophone Location	Mine Signal Location	Mine Elevation
711	25086.50	40262.40	1088.40			
PM#2	24975.12	40610.08	1133.26			
TEMP	25075.98	40881.94	1197.06			
T1	25192.52	41065.72	1186.29	#3	Entry #7, XC17	
T2	25131.07	41032.20	1202.13	#2, #6 (buried)	Entry #7, XC18	760.74
T3	25036.23	40980.39	1206.51	#4		
T4	25083.37	41120.04	1202.00	#1, #5 (buried)		
	25253.94	41099.31			Entry #7, XC16	
	25315.37	41132.86			Entry #7, XC15	

### 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 #7, crosscut #18 and performed the pounding cycles.

The **underground team** consisted of:

- The mine representative
- Dr. Yi Luo - Associate Professor, WVU
- James Pinkley - Hilti, Inc.
- Hayden Whittam - Hilti, Inc.

The **surface team** consisted of:

- Bohdan Nedilko - Weir-Jones Consulting
- Monte Hieb - WV-DMHS&T
- Dr. Keith Heasley - Associate Professor, WVU
- Dr. Syd Peng - Professor, WVU
- Dr. Roy Nutter - Professor, WVU
- Jun Lu - Graduate Student, WVU
- Becky Hardy - Graduate Student, WVU
- Others

## Equipment

The geophones used in the study were Geospace 32CT elements. These geophones have a spectral band from ~10 Hz to > 500 Hz (3dB down at ~7 Hz). The surface packages have one sensor along each orthogonal axis, three sensors in all. The downhole sensor packages have five tri-axial orthogonal arrays. Thus, there are five sensors along X-axis, five sensors along Y-axis, five sensors along Z-axis. The individual readings from each of the axis are added up to cancel out the noise and improve the response of the sensor package to the ground vibration. The digitizer (from Terrasciences Systems) was 24 bit with 24 channels (of which we used 18) and the data was sampled at 2000 samples per second. The data was viewed, analyzed and stored on a portable PC at the site.

## Test Protocol

For the underground signaling, a number of different devices and pounding locations were used. The signaling devices included: a Hilti DX76, a Hilti DX460, a Hilti DX462, an 8 lb sledge hammer, and a crib block. For locations, the Hilti tools and pounding were performed: directly on the roof, on the roof bolt, and on the coal rib. For each combination of signaling device and location, 5 hits were performed and then a pause of 30 seconds. During the signaling, the exact time that the pounding for each device started was recorded. After a complete cycle, the underground team moved to the next location. The complete record of the underground signaling is included in Table 3 at the end of this report.

## Initial Results

Upon quickly reviewing the results directly after the test, we were able to see a good strong response from 9 different signal sets underground (see Table 2). From reviewing the seismic data, we found that:

Table 2. Seismic Results of the Underground Signaling (adjusted 6/07)

Time	Signal	Peak Particle Velocity (m/s)	Surface Geophone Location	Source Location (441' deep)	Horiz. Offset (ft)
9:05:00	Sledgehammer on Roof Rock	0.000074	Vert-Buried-#2	Entry #7, XC #18	0
9:05:34	Sledgehammer on Roof Bolt	0.000038	Vert-Buried-#2	Entry #7, XC #18	0
9:06:12	Crib Block on Roof Rock	0.000095	Vert-Buried-#2	Entry #7, XC #18	0
9:06:42	Crib Block on Roof Bolt	0.000079	Vert-Buried-#2	Entry #7, XC #18	0
9:30:08	Sledgehammer on Roof Rock	0.000039	Vert-Buried-#2	Entry #7, XC #17	70
9:30:42	Crib Block on Roof Rock	0.000085	Vert-Buried-#2	Entry #7, XC #17	70
9:31:10	Crib Block on Roof Bolt	0.000086	Vert-Buried-#2	Entry #7, XC #17	70
10:03:36	Sledgehammer on Roof Rock	0.000025	Vert-Buried-#2	Entry #7, XC #16	140
10:04:07	Crib Block on Roof Rock	0.000042	Vert-Buried-#2	Entry #7, XC #16	140

- 1) The crib block on the rock appeared to be the strongest signal, followed by the crib block on the bolt, the sledgehammer on the roof rock and the sledgehammer on the roof bolt. (see Table 2).
- 2) The Hilti tools were only barely detectable when they were directly underneath the geophone, although they were obviously the loudest underground. We suspect that they may generate higher frequencies signals which attenuate fast. This is an area to investigate further.
- 3) We had very good detectable signals at horizontal offsets of 0, 70 and 140. At 210 ft of horizontal offset, you could maybe say there was signal detection, but without knowing the time of the signal, it would be hard to pull the signal from background noise.
- 4) We detected the strongest signals from the 0 and 70 ft offset with both buried and surface geophones. The buried geophones provided about twice the peak particle velocity.
- 5) In analyzing the seismic magnitude, it is appears that just the increase in distance between the source and signal is not responsible for all of the signal attenuation that we see. We hypothesize that the incident angle between the “polarized” source and the sedimentary layers may be causing refraction/reflection (or some other mechanism) and greatly attenuating the non-perpendicular seismic signal.

## **Future Work**

In the future, we will be analyzing the seismic signals in more detail. We plan to better quantify the magnitudes of all the signals in all of the sensor directions. Also, we plan to apply some filtering to clean up the signals and better accentuate the recording pounding.

## **Acknowledgements**

We would like to acknowledge the companies who have graciously volunteered their assistance in this field test and have enabled this critical research to proceed. First, we would like to thank 4 West Mine of Dana Mining Co. of PA, Inc. 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 Weir-Jones Consulting for providing the seismic equipment and personnel to record the seismic data and for assisting in subsequent interpretation and analysis of the data. Finally, we would like to thank Hilti, Inc. for providing the equipment and personnel to test the seismic response of the powder-actuated fasteners as a potential seismic source.

**Table 3. Activity Log of the Underground Signaling  
Seismic Testing at 4 West Mine, Underground Activity Log**

Date: 09/30/06

Starting Time	Relative Power Level	Activity	No.	Notes
At Entry #7, Crosscut #18				
9:00:00	5	Hilti DX460 on Roof Rock	5	
9:01:30	10	Hilti DX76 on Roof Rock	5	
9:03:00	7	Hilti DX 462 on Roof Bolt Plate	5	
9:04:05	10	Hilti DX76 on Roof Bolt Plate	5	
9:05:05	1	Hammer on Roof Rock	5	
9:06:00	2	Hammer on Roof Bolt	5	
9:06:30	2	Crib Block on Roof Rock	5	
9:07:00	2	Crib Block on Roof Bolt	5	
9:09:45	5	Hilti DX460 on Rib	5	
9:10:10	1	Hammer on Rib	5	
9:10:50	2	Crib Block on Rib	5	
At Entry #7, Crosscut #17				
9:20:20	5	Hilti DX460 on Roof Rock	5	
9:22:30	10	Hilti DX76 on Roof Rock	3	
9:23:28	10	Hilti DX76 on Roof Rock	5	More Powerful Cartridge used
9:25:55	7	Hilti DX 462 on Roof Bolt Plate	5	
9:27:20	10	Hilti DX76 on Roof Bolt Plate	5	2nd Shot on/wood plate board
9:30:00	1	Hammer on Roof Rock	5	
9:30:30	2	Hammer on Roof Bolt	5	
9:31:20	2	Crib Block on Roof Rock	5	
9:31:40	2	Crib Block on Roof Bolt	5	
9:32:15	5	Hilti DX460 on Rib	5	
9:33:15	1	Hammer on Rib	5	
9:33:55	2	Crib Block on Rib	5	
At Entry #7, Crosscut #16				
9:41:30	5	Hilti DX460 on Roof Rock	5	
9:42:40	10	Hilti DX76 on Roof Rock	5	
9:43:40	7	Hilti DX 462 on Roof Bolt Plate	5	
9:44:40	10	Hilti DX76 on Roof Bolt Plate	5	
9:45:40	1	Hammer on Roof Rock	5	
9:46:05	2	Hammer on Roof Bolt	5	
9:46:35	2	Crib Block on Roof Rock	5	
9:47:00	2	Crib Block on Roof Bolt	5	
9:46:10	5	Hilti DX460 on Rib	5	
9:48:55	1	Hammer on Rib	5	
9:49:50	2	Crib Block on Rib	5	

At Entry #7, Crosscut #16 (Repeat)				
10:00:00	5	Hilti DX460 on Roof Rock	5	
10:01:03	10	Hilti DX76 on Roof Rock	5	
10:02:40	10	Hilti DX 462 on Roof Bolt Plate	5	
10:03:20	1	Hammer on Roof Rock	5	
10:03:45	2	Hammer on Roof Bolt	5	
10:05:00	2	Crib Block on Roof Rock	5	
10:05:35	2	Crib Block on Roof Bolt	5	
10:06:00	10	Hilti DX76 on Roof Bolt Plate	5	
10:07:30	5	Hilti DX460 on Rib	5	
10:08:00	1	Hammer on Rib	5	
10:08:35	2	Crib Block on Rib	5	
At Entry #7, Crosscut #15				
10:30:00	5	Hilti DX460 on Roof Rock	5	
10:30:50	10	Hilti DX76 on Roof Rock	5	
10:32:00	7	Hilti DX 462 on Roof Bolt Plate	5	
10:32:45	10	Hilti DX76 on Roof Bolt Plate	5	
10:33:42	1	Hammer on Roof Rock	5	
10:34:00	2	Hammer on Roof Bolt	5	
10:35:15	2	Crib Block on Roof Rock	5	
10:35:40	2	Crib Block on Roof Bolt	5	
10:35:55	5	Hilti DX460 on Rib	5	
10:36:17	1	Hammer on Rib	5	
10:36:44	2	Crib Block on Rib	5	