

Results from Analysis of Seismic Data for the January 2, 2006 event near Sago, WV

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Introduction

The author examined regional seismic network recordings for the time interval around 6:30 AM, EST January 2, 2006 to determine if the event at the Sago mine was seismically recorded.

A small amplitude signal was identified on records at broadband station MCWV, near Mont Chateau, WV, the nearest seismic station to the mine. This station is part of the U.S. Geological Survey Advanced National Seismic System (ANSS) which is designed to record world-wide seismic activity as well as to monitor shocks in all regions of the U.S. The signal was also recorded at larger distances by three stations to the south: FWV, ELN and BLA. These more distant stations use short period sensors and are operated by Virginia Tech as part of the ANSS.

The following is a summary of the results pertaining to the location and time of the event that generated the seismic signals.

Data

Figures 1 through 4 show the data recorded at stations MCWV, FWV, ELN and BLA respectively. The signals have been bandpass-filtered using a 3 pole Butterworth prototype with corner frequencies 1.0 and 5.0 Hz. The signal/noise ratios of these data are small, however, measurement of arrival times for P and S waves was possible. The estimated arrival times are given below in Table 1, *in Eastern Standard Time*.

The coordinates of the recording stations are as follows:

BLA:	37.2113 deg N	80.4202 deg W
ELN:	37.2805 deg N	80.7517 deg W
FWV:	37.5810 deg N	80.8118 deg W
MCWV:	39.6582 deg N	79.8457 deg W

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Results

Figure 5 shows the epicenter estimated using the arrival time data in Table 1. The locations were determined using the velocity model in Table 2, in conjunction with the computer program **Hypoellipse**. Table 3 gives hypocenter and origin time estimates for 3 cases.

The first case assumes that the focal depth of the source is near the ground surface, consistent with a mining-related source, but not necessarily located near the Sago mine. Latitude, longitude and origin time are treated as unknowns to be determined from the arrival time data. The origin time estimate in this case is 06:26:38.29 EST with standard error 1.65 seconds. The 68% confidence ellipse for the epicenter determined from the seismic data includes the Sago mine location (Figure 5). A 68% confidence interval for the origin time is 06:26:36.60 to 06:26:39.94 EST, assuming no systematic bias due to uncertainty associated with the velocity model in Table 2 or in phase arrival time measurement.

The second case is a completely un-constrained location, in which the latitude, longitude, focal depth and origin time are treated as unknowns to be determined. The computed epicenter is very near the Sago Mine location in this case (figure 5). The estimated focal depth is shallow (2.5 km) but very poorly determined (68% confidence: 0 to 34 km). The 68% confidence interval for the origin time is 06:26:35.35 - 06:26:41.21 EST.

The third case assumes that the source occurred at the Sago mine, (Latitude 38.9407°N; Longitude 80.2030°W) with zero focal depth. The only free parameter to be determined is the origin time. The 68% confidence interval for the origin time is 06:26:36.46 - 06:26:40.00 EST.

Conclusions

The seismic signal recorded on January 2, 2006 at approximately 06:26 EST was caused by an underground disturbance at or near the Sago mine. Assuming that the source was at the Sago mine, a 68% confidence interval for the origin time is 06:26:36.46 - 06:26:40.00 EST. Simply put, the event most likely occurred within a 4 second interval centered at 06:26:38.2 AM. This estimate assumes no systematic error in phase arrival time determination, and/or bias in the seismic wave velocity model used for analysis. It is possible that the origin time estimate is slightly late, due to the very emergent nature of the P and S wave arrivals because of low signal/noise ratios at all the recording stations.

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Table 1

Station	P arrival*			S arrival*		
	Hour	Minute	Second	Hour	Minute	Second
MCWV	06	26	52.6	06	27	3.5
FWV	06	27	5.1	06	27	24.1
ELN	06	27	9.0	06	27	32.7
BLA	06	27	9.7	06	27	32.2

* All times are Eastern Standard Time.

Table 2

P wave velocity (km/sec)	S wave velocity (km/sec)	Layer thickness (km)
5.63	3.43	5.7
6.05	3.52	9.0
6.53	3.84	36.0
8.18	4.78	-

Table 3

	Latitude	Longitude	Focal Depth	Origin Time*	Standard Error of Origin Time	Azimuth of Error Ellipse Semi-Major Axis	Major Axis Length	Minor Axis Length
Depth constrained	38.9243°N	80.1169°W	0 km (fixed)	06:26:38.29	1.65 s	286°	23 km	4.4 km
Depth unconstrained	38.9465°N	80.1920°W	2.45 km	06:26:38.28	2.93 s	289°	23 km	4.0 km
Depth and location constrained	38.9407°N (fixed)	80.2030°W (fixed)	0 km (fixed)	06:26:38.23	1.77 s			

* All times are Eastern Standard Time.

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Seismic Data Recorded on January 2, 2006
at Station MCWV (Mont Chateau, West Virginia, distance 85 km)

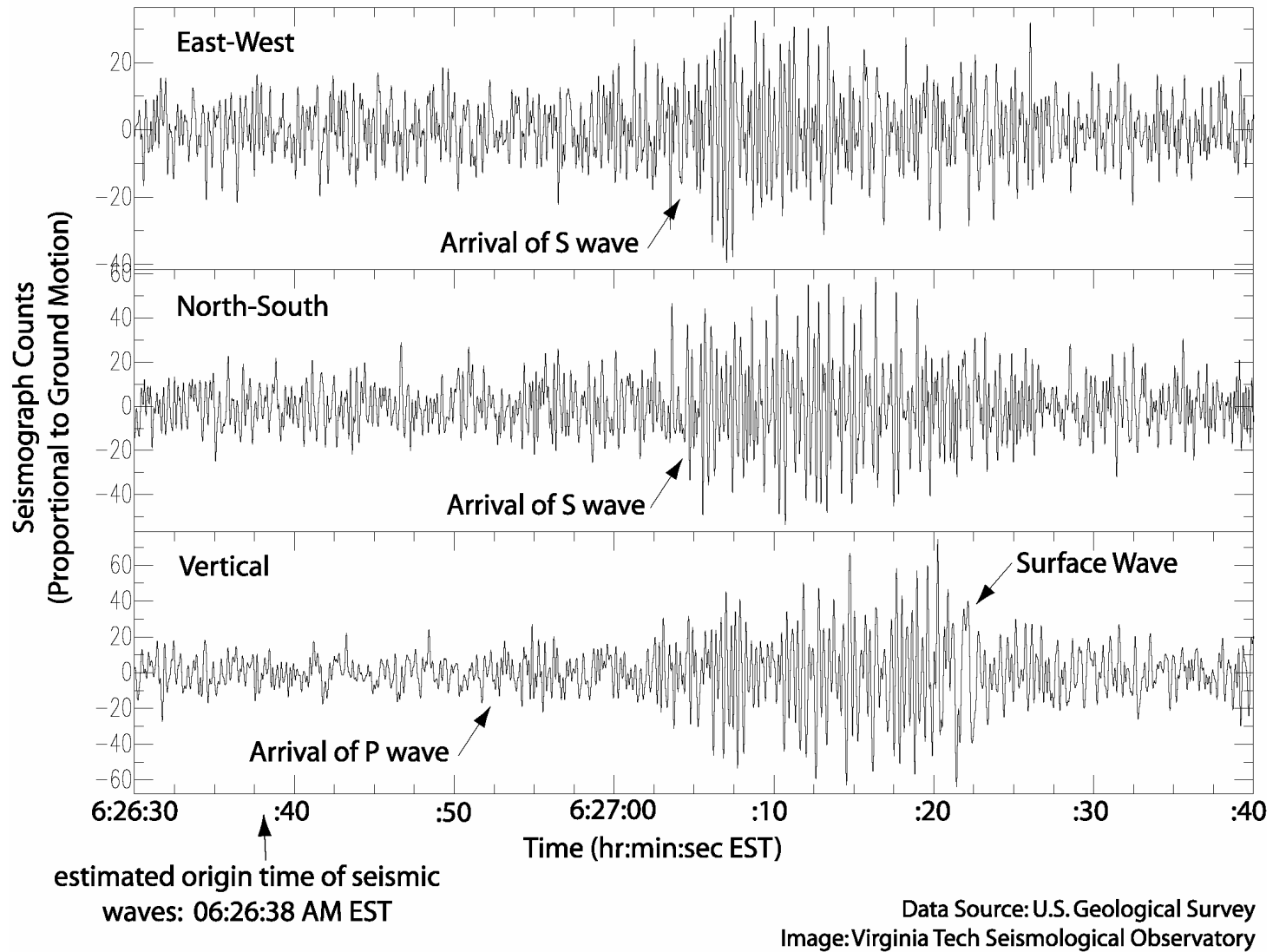


Figure 1. Waveforms recorded at station MCWV, 85.4 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

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Seismic Data Recorded on January 2, 2006
at Station FWV (Forest Hill, West Virginia, distance 160 km)

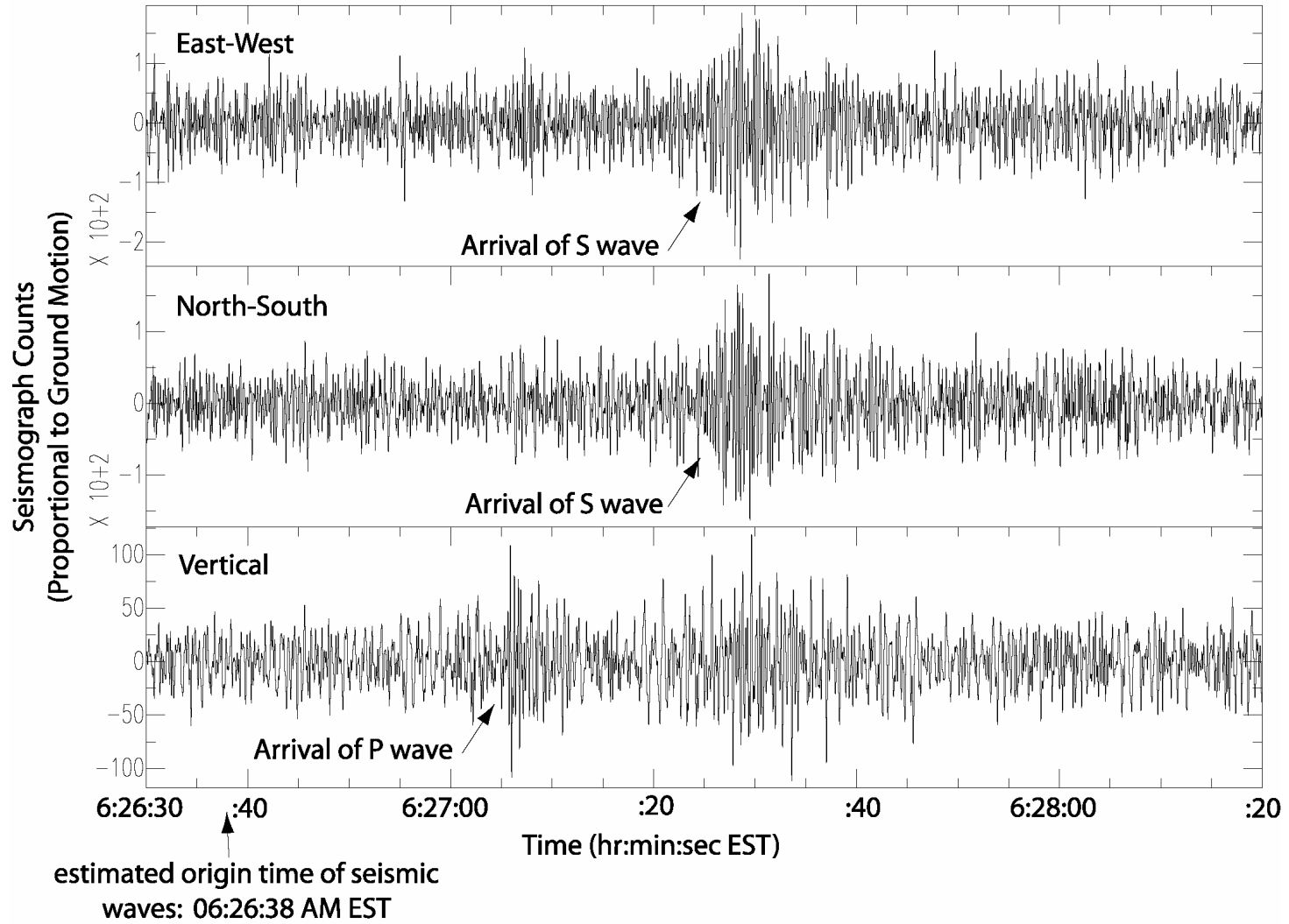


Figure 2. Waveforms recorded at station FWV, 160.1 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

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Seismic Data Recorded on January 2, 2006
at Station ELN (Prospectdale, Virginia, distance 191 km)

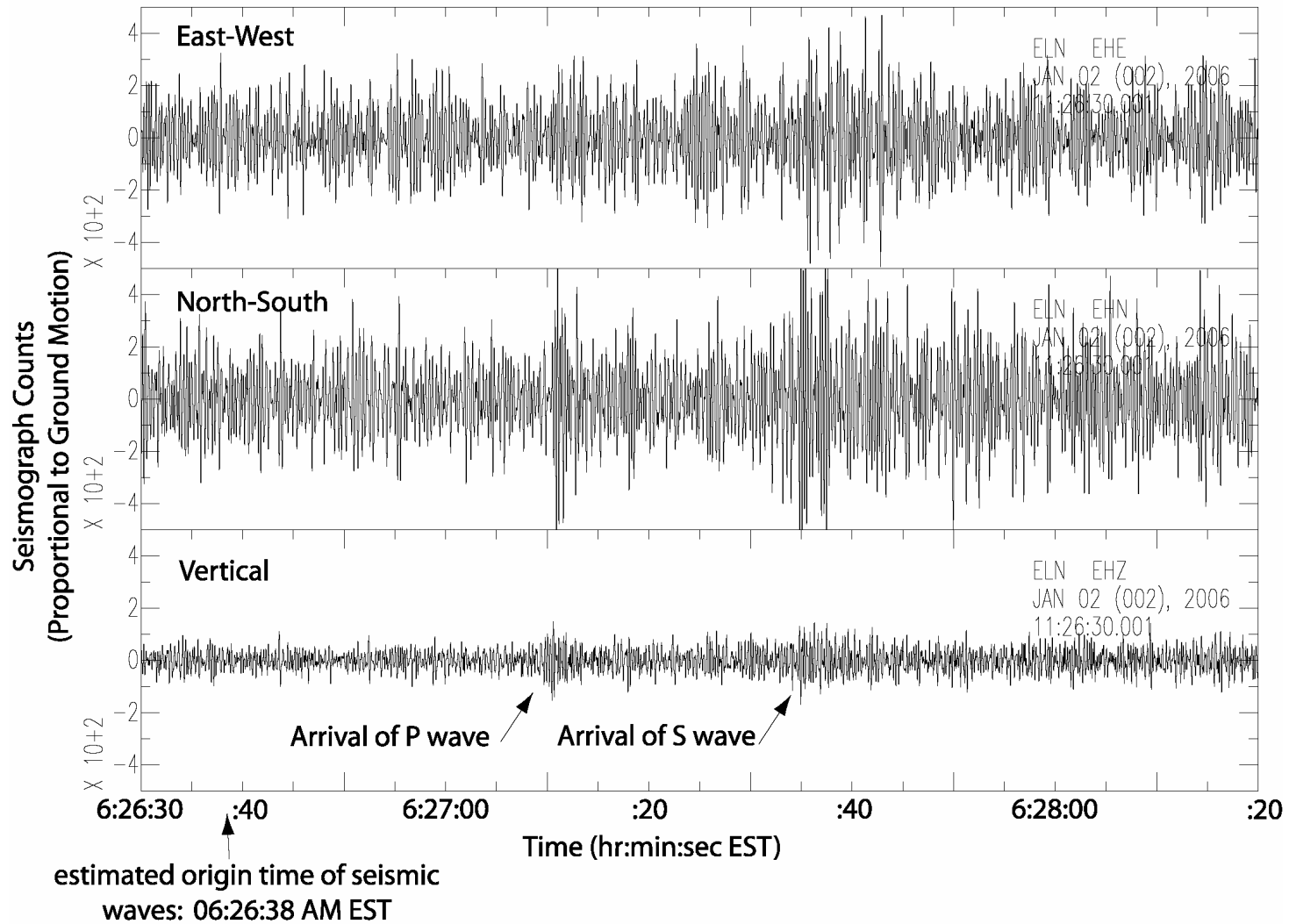


Figure 3. Waveforms recorded at station ELN, 190.5 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

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Seismic Data Recorded on January 2, 2006
at Station BLA (Blacksburg, Virginia, distance 193 km)

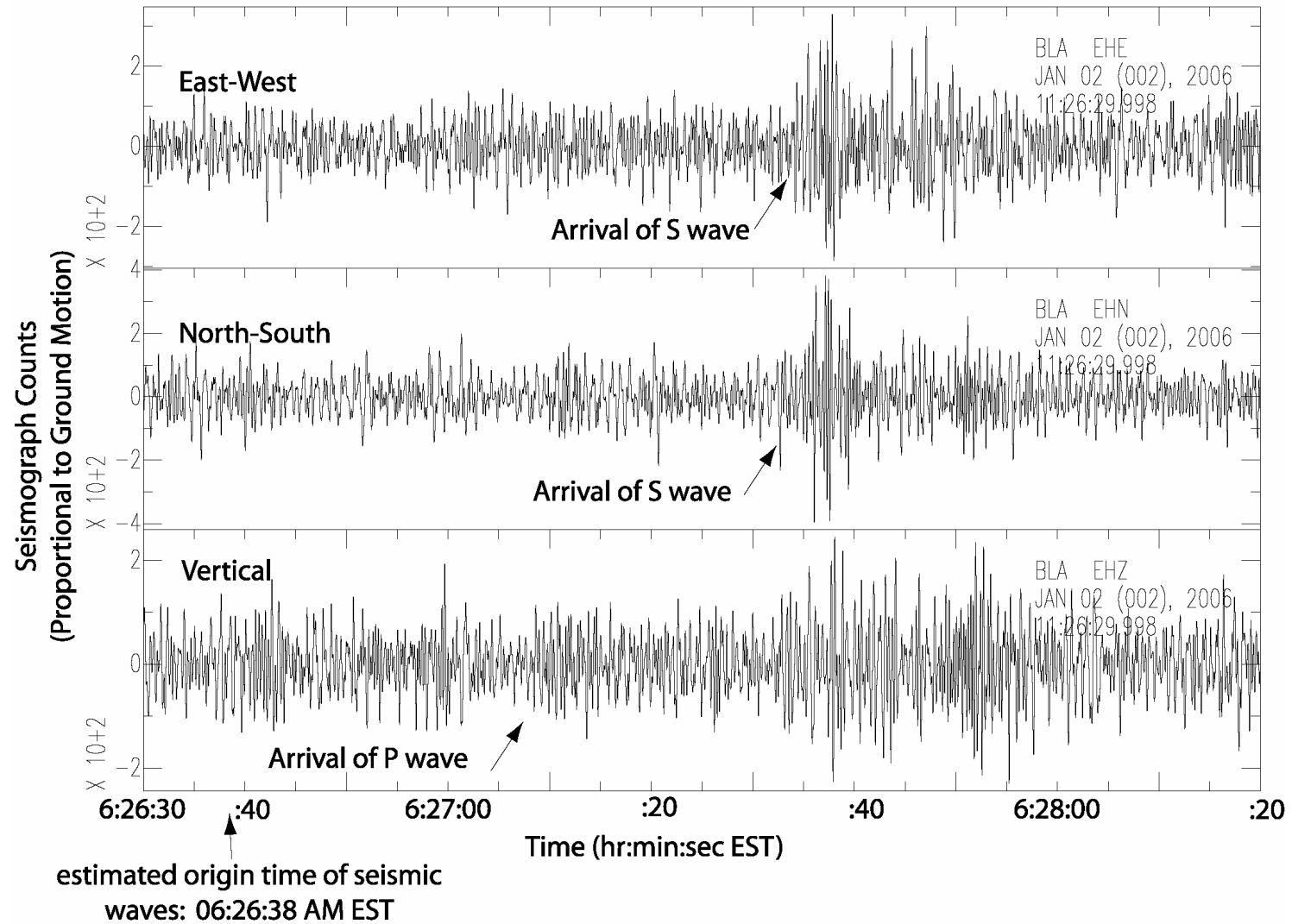


Figure 4. Waveforms recorded at station BLA, 192.9 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

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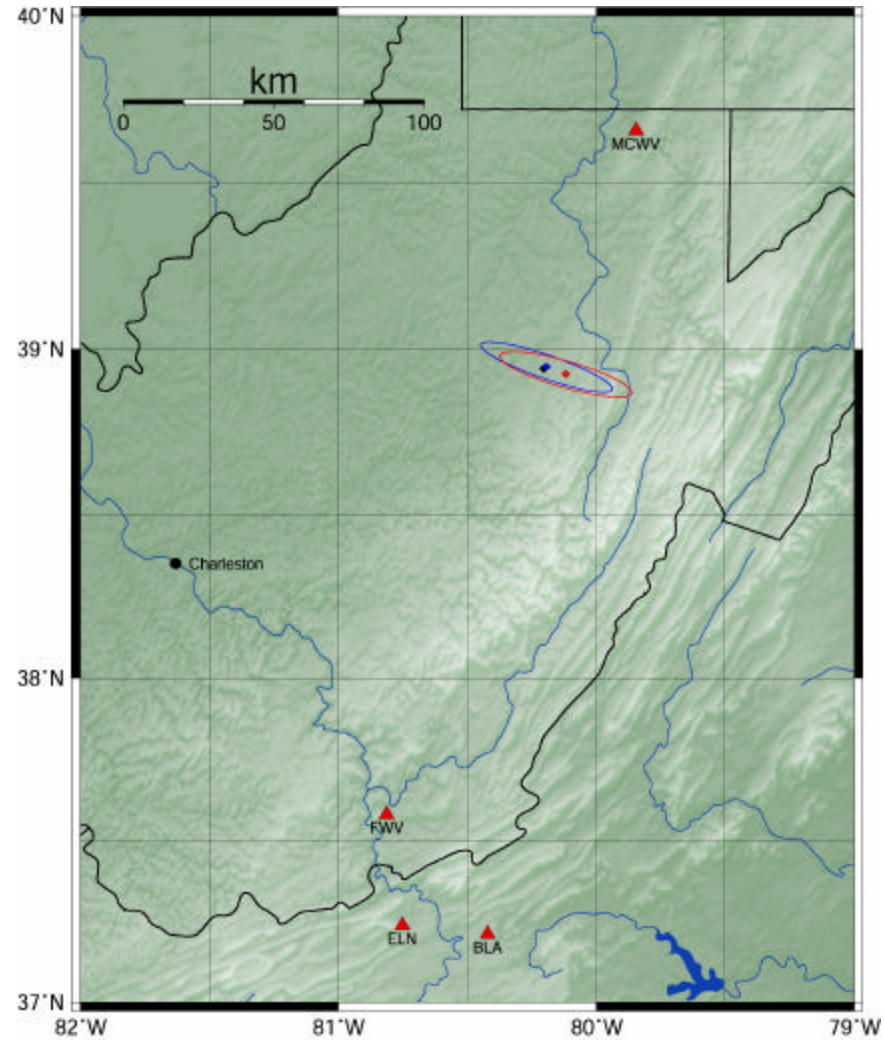


Figure 5. Map showing as a black diamond the assumed location of the Sago mine event (38.94065 degrees N, 80.20295 degrees W). The red diamond shows the epicenter determined using the arrival time data in Table 1 with focal depth fixed at the ground surface. The red line indicates 68% confidence ellipse for the epicenter location. The blue diamond is the epicenter estimated with the depth unconstrained. The blue line shows the corresponding 68% confidence ellipse. Seismic stations used in the location are indicated by the red triangles.