Hernandez, Alysha

From: Stark, Jim
Sent: Wednesday, February 01, 2012 8:01 AM
To: Hernandez, Alysha
Subject: FW: Q42011 SOD Mircorseismic Report
Attachments: Q42011_SOD Microseiesmic Report.pdf

Alysha,

Please scan this into West Elk C-1980-007 Reports when you get a chance. Thanks.

From: Welt, Kathy [mailto:KWelt@archcoal.com]
Sent: Tuesday, January 31, 2012 17:41
To: Stark, Jim
Subject: FW: Q42011 SOD Mircorseismic Report

For the Division's files, attached is the North Fork Valley Seismic Network Monitoring Report for the 4th Quarter 2011. No unusual seismic events were recorded.

Kathy Welt,
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From: Koontz, Wendell
Sent: Tuesday, January 31, 2012 4:02 PM
To: Welt, Kathy
Subject: Q42011 SOD Mircorseismic Report

Kathy

Attached is the 4th quarter report for distribution.
Please let me know if you have questions.

Thanks

Wendell

Wendell Koontz
Sr. Mine Geologist
Ark Land Company
West Elk Mine
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FINAL REPORT

NORTH FORK VALLEY SEISMIC NETWORK MONITORING REPORT

FOURTH QUARTER 2011

MOUNTAIN COAL COMPANY
WEST ELK MINE
SOMERSET, COLORADO

31 January 2012

Prepared by
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URS
Seismic Hazards Group
URS Corporation
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SUMMARY

During the three-month period from 1 October to 31 December 2011, 70 mining-related seismic events of approximate coda magnitudes (M_C) 1.7 and larger were relocated using data recorded on the North Fork Valley Seismic Network. Most of the seismic events were located at the Elk Creek Mine. With the exception of the Elk Creek Mine activity, the quarter was quiet in terms of seismicity. Only two seismic events occurred within the West Elk Mine permit area. The largest of the two seismic events was a M_C 1.8 event, located less than 1 km from the area of active mining. The event occurred on 13 November at 03:46 GMT. The largest earthquake this quarter in North Fork Valley was M_L 3.0 event on 19 October at Elk Creek Mine. This earthquake also had the highest peak horizontal ground acceleration (PGA) observed during the fourth quarter, 0.006 g recorded at station FGH at a distance of approximately 2.26 km (1.40 mi). The highest PGA recorded at the West Elk Mine was 0.0002 g at station MCD resulting from the M_C 1.8 event on 13 November located approximately 3.99 km (2.48 mi) away.

INTRODUCTION

This report has been prepared in partial fulfillment of a commitment by Mountain Coal Company (MCC) to monitor seismicity (including the microseismic activity near the longwall mining activity) in the North Fork Valley just east of Paonia, Colorado. This commitment is to the Colorado Department of Natural Resources, Division of Reclamation, Mining and Safety. This report contains analyses of the data collected for the fourth quarter of 2011 (1 October through 31 December).

The area included in this study encompasses the West Elk Mine operated by MCC and Bowie No. 2 Mine, property of Bowie Resources, LLC (BRL) (Figure 1). Seismicity from the Elk Creek Mine, owned by Oxbow Mining, Inc. is also recorded on the North Fork Valley Seismic Network (NFVSN).

The original 10-station NFVSN was established to (1) monitor the mining-related seismicity occurring in the vicinity of the West Elk and Bowie No. 2 mines at a detection threshold magnitude of M_L 1.0, (2) provide event locations and magnitudes and estimates of ground motions, and (3) determine focal mechanisms when feasible. Installation of the NVFSN began in 2006 and by October of that year, five stations were in operation (Swanson *et al.*, 2007). By July 2006, the original 10 stations were operational. Currently 13 stations are in operation.

NETWORK OPERATIONS

The NFVSN currently consists of 13 stations (Table 1 and Figure 1), which have been installed as a cooperative effort between MCC, BRL and the Spokane Research Laboratory of the National Institute of Occupational Safety and Health/Centers for Disease Control and Prevention (NIOSH/CDC). One temporary station OXM was installed in February 2009 and has remained as part of the network (Table 1 and Figure 1). A semi-permanent station, NOB, was installed in November 2009 in the Bowie Mine area. A permanent station was installed at Fire Mountain (FMT) and began operations at Elk Creek Mine in October 2010. The following factors were

used to determine the station locations: access, permission of land owners, network geometry, radio line-of-sight to the common recording site at Paonia Airport or a repeater station, and uniform coverage of the target area (Figure 1). Each station consists of three-component accelerometers. The locations of seismographic stations operating during the 2011 fourth quarter are presented in Table 1 and shown on Figure 1.

Table 1. Seismograph Stations of the North Fork Valley Seismic Network

Station	Latitude (degrees)	Longitude (degrees)	Elevation (ft) [m]	Station Correction (sec)	Station Name	Owner
BWK	38.928	-107.537	6701 [2042]	-0.139	Bowie King Mine	BRL
FGH	38.948	-107.536	7201 [2195]	-0.087	Freeman Gulch Hubbard	BRL
FMT	38.917	-107.482	8497 [2590]	0.117	Fire Mountain	NIOSH
LLM	38.857	-107.461	8240 [2512]	0.042	Lion Mesa	MCC
MCD	38.881	-107.474	7274 [2217]	-0.079	Minnesota Creek Dam	MCC
MFB	38.956	-107.559	7924 [2415]	-0.002	Middle Forest Boundary	BRL
NOB	38.973	-107.542	7644 [2330]	0.109	North Bowie	BRL
OXM	38.961	-107.493	8130 [2139]	0.030	Oxbow Mine	NIOSH
SPG	38.872	-107.425	8174 [2491]	0.033	South of Poison Gulch	MCC
SEF	38.874	-107.390	8667 [2642]	0.101	South of East Flatiron	MCC
TCR	38.982	-107.564	8483 [2586]	0.075	Terror Creek Dam	BRL
WFW	38.901	-107.424	8433 [2570]	0.068	West Flatiron West	MCC
WTM	38.941	-107.591	7954 [2424]	0.002	West Tower Mountain	BRL

The development of NFVSN is described in previous reports. Real-time processing utilizes modules from the *Earthworm* software suite developed by the U.S. Geological Survey (USGS) in Menlo Park, California (Johnson *et al.*, 1995). The program detects, automatically locates, and saves event data for triggered events. The network is divided into two sub-nets (each with six-stations), one in each of the two main mining areas (Figure 1).

DATA PROCESSING

Identification of Events

Events are regarded as seismic in origin and logged by the *Earthworm* triggering system if they appear on five or more stations with significant amplitude, impulsive onset and appropriate time differences between stations. Triggering occurs within the two sub-nets (six stations in each) so that important events are not missed. *Earthworm* also provides automatic locations for events that have sufficient arrival time picks. During the fourth quarter, *Earthworm* detected and located 1,805 events (not all of which were seismic events). This is slightly more than the number of triggers from the previous quarter. Many more triggered waveform files were recorded of which many have insufficient station data for locating the events.

We reviewed the daily summary or heliocorder records (these are continuous recordings of 12-hour periods conveniently plotted on one page) for filtered traces at three stations (WTM, LLM and WFW; Figure 1). We also reviewed the list of events automatically detected and located by *Earthworm*. Events were chosen based on amplitudes on the heliocorder records at the three stations. We measured the amplitudes on these heliocorder records for events known to be M_C 1.7 or greater in size at the different mining locations and used that as a guide for selecting other events of approximate M_C 1.7 and larger.

Location Methodology

We used the utility SUDSPICK in the program PC-SUDS (Banfill, 1996) to pick P- and S-wave arrival times within the DMX files (triggered waveform data files) for our selected list of events. Another utility within PC-SUDS, XTYHY71, was used to extract the arrival time picks from the waveform data files and convert them to the correct format to be used in the location program HYPO71 (USGS, 1975). Only events with at least 8 arrival time picks were located. The location accuracy usually improves as the number of stations increases.

A DOS version of the location program HYPO71 was used to locate the earthquakes. HYPO71 requires a plane-layered velocity model, indicating depths to the top of each constant velocity layer, as well as station locations and arrival times, in order to relocate the earthquakes. The velocity model (Table 2) was determined from a detailed seismic study at the West Elk Mine (Swanson and Koontz, 2006). In that study, the recording stations were directly above the mining panel and so all the seismic rays were considered to be direct rays. Station elevation corrections (Table 1) were incorporated into the location program based on the elevation differences between the station and the velocity model datum (2420 m [7938 ft]) and using a weighted average velocity over the layers between the datum and the station elevation.

Table 2. Velocity Model Used in Locating Earthquakes

Depth to Top of layer (km) [mi]	Velocity (km/sec) [ft/sec]
0.00 [0.00]	2.21 [7,251]
0.07 [0.04]	2.73 [8,957]
0.27 [0.17]	3.01 [9,876]
0.37 [0.23]	3.18 [10,434]
1.00 [0.62]	3.9 [12,796]
1.50 [0.93]	4.60 [15,093]
2.50 [1.55]	5.20 [17,061]
3.50 [2.17]	6.00 [19,686]
6.00 [3.73]	6.5 [21,327]

Magnitude Estimation

M_L magnitudes are generally provided for the larger events recorded ($M_L \geq 3.0$) and located by the National Earthquake Information Center (NEIC). There was only one event reported by the NEIC during the fourth quarter, a M_L 3.0 earthquake on 19 October. M_C values are automatically calculated by *Earthworm*, based on a USGS northern California formula. M_C values are approximately equivalent to M_L.

RESULTS

Seismic Event Locations

Table 3 lists the 73 events recorded and relocated ($M_C \geq 1.7$) in the fourth quarter. The date and origin time (hours, minute, and second) of the event, location (latitude, longitude, and general area), magnitude, and largest PGA values (in g's; 1g = 980 cm/sec^2) are listed.

Figure 2 shows the resulting locations for the mining-related seismic events of approximate M_C 1.7 and larger. Note event locations are better constrained when they occur within the perimeter of the seismic network (greater azimuthal coverage). The events are located throughout the study area but the vast majority are concentrated in the Elk Creek Mine area, with two events in the West Elk Mine Permit Area (Figure 2). The largest recorded event during this quarter was a M_L 3.0 event on 19 October at 05:24 GMT in the Elk Creek Mine.

Three possible tectonic events occurred during the fourth quarter: two within the Elk Creek Mine on 7 November and 13 December with magnitudes of M_C 2.0 and 1.7, respectively, and one M_C 2.0 event in the West Elk Mine area on 12 November (Figure 2 and Table 3). The events exhibited some compressional first motions ("up") at approximately half of the NFVSN stations. The mining-related seismic events that have been observed to date by the NFVSN generally exhibit all dilatational ("down") first motions, typical of coal mine seismicity in Utah (e.g., Wong and McGarr, 1990). One event on 7 November remains questionable due to the shallow focal depth, above 0.9 km, and the location within the area of active mining (Figure 2). The other two possible tectonic events on 12 November and 13 December were below the depth of active mining, 2.4 km and 4.6 km, respectively.

Seismic Event Magnitudes

Of the 70 mining-related events, 68 were assigned magnitudes (Table 3). M_C values assigned by *Earthworm* are also listed in Table 3.

Recorded Peak Ground Accelerations

PGA values are generally recorded for all triggered events on the three-component accelerometers. We have included the largest PGA recorded for each relocated seismic event in Table 3 when available, along with the station that recorded the ground motion and the event-to-station distance. The largest PGA recorded during the fourth quarter was 0.006 g at station FGH for the 19 October 05:24 GMT M_L 3.0 event at a distance of approximately 2.26 km (1.40 mi). This event occurred at the Elk Creek Mine. The largest PGA recorded at the West Elk Mine was 0.0002 g at station MCD resulting from the 13 November 03:46 GMT M_C 1.8 seismic event that occurred at a distance of approximately 3.99 km (2.48 mi). Note distances are approximate given uncertainties in the event locations due to uncertainties in the velocity model used in the relocations.

ACKNOWLEDGMENTS

The NFVSN data analysis and evaluation are jointly supported by MCC and BRL. Our thanks to Wendell Koontz, MCC Project Manager, and Jim Abshire, BRL Project Manager for their support. Our appreciation to Pete Swanson (NIOSH/CDS) for his operation and maintenance of the network. Our thanks to Melinda Lee for her assistance in the preparation of this report.

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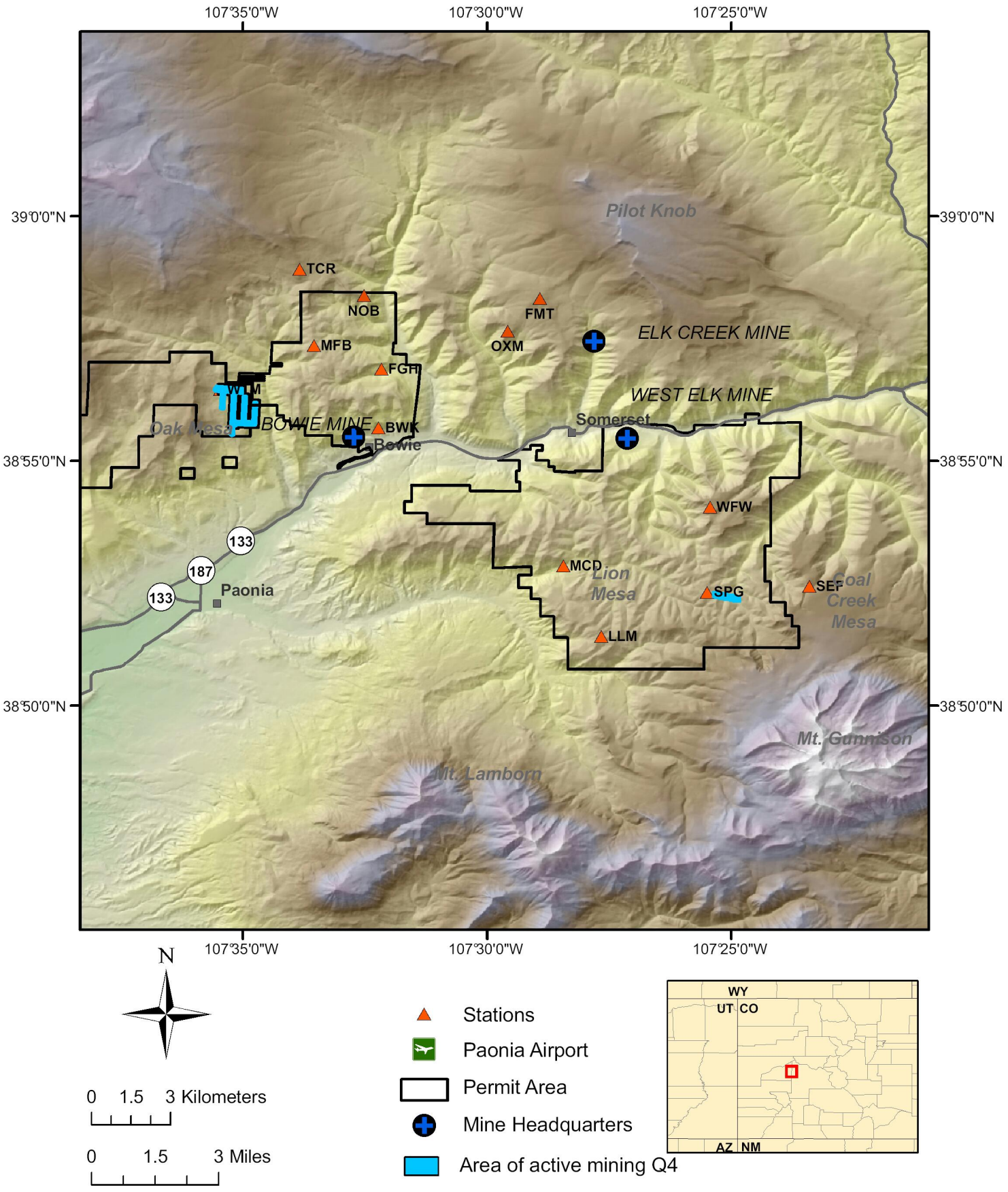
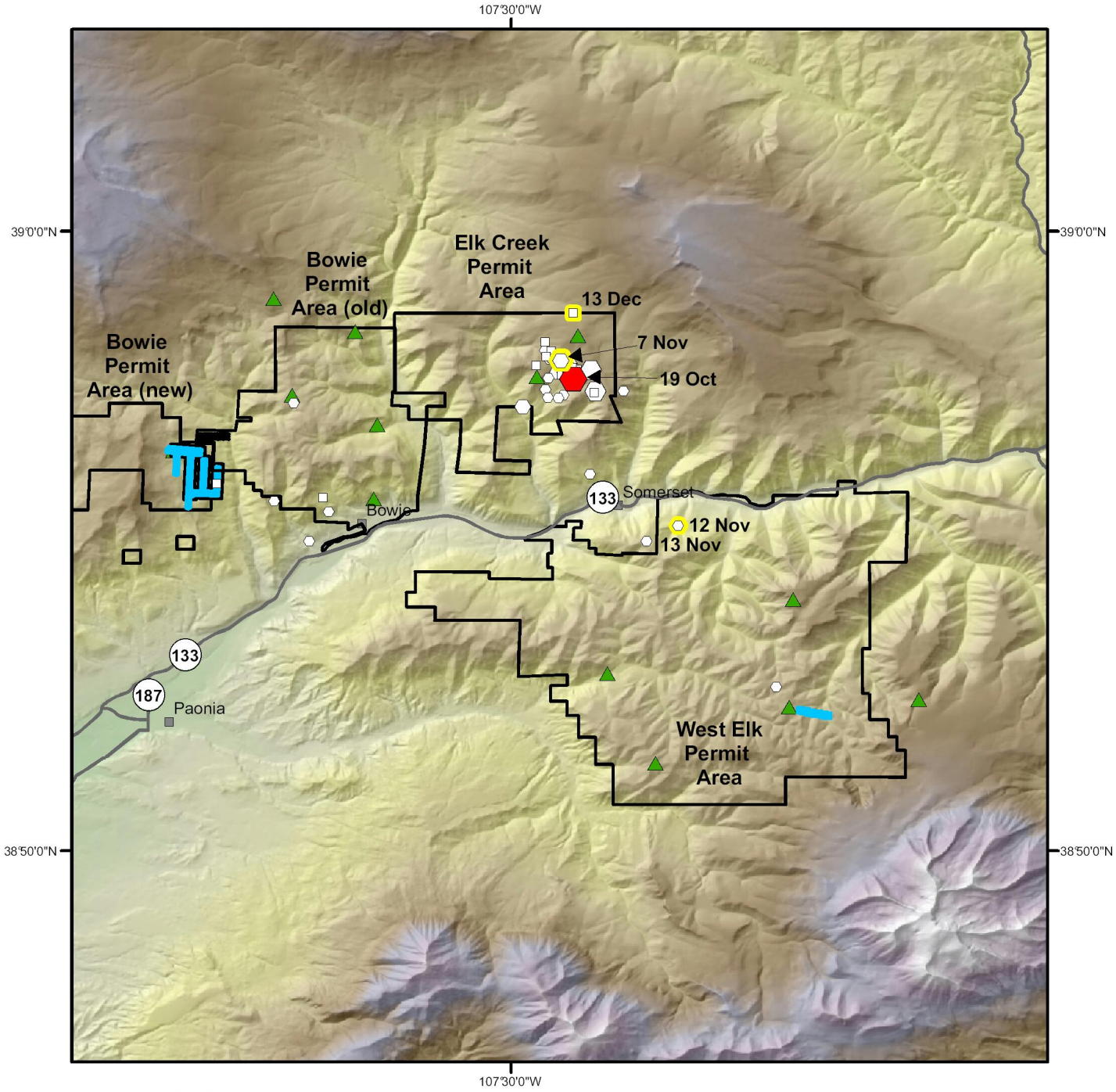
Year	Month	Day	Hour	Minute	Sec	Latitude	Longitude	DEPTH	ML	MC	Location	Location Quality	Station	PGA (g)	Distance (km)
2011	10	1	15	37	22.54	38.9622	-107.4843	0.00		1.7	Elk Creek	B1	FGH	0.00006	2.35
2011	10	1	21	17	57.45	38.9620	-107.4860	0.00		1.9	Elk Creek	B1	FGH	0.00012	2.30
2011	10	2	4	16	36.59	38.9633	-107.4830	0.81		2.0	Elk Creek	B1	FGH	0.00008	2.47
2011	10	3	5	19	12.32	38.9570	-107.4697	1.25		1.7	Elk Creek	B1	FGH	0.00004	2.48
2011	10	3	14	27	16.32	38.9642	-107.4847	0.88		2.1	Elk Creek	B1	FGH	0.00016	2.49
2011	10	4	0	3	49.65	38.9638	-107.4857	0.92		1.7	Elk Creek	B1	FGH	0.00014	2.44
2011	10	4	18	23	47.29	38.9663	-107.4905	0.84		0.0	Elk Creek	B1	No strong motion data		
2011	10	4	18	23	39.39	38.9662	-107.4892	0.78		2.1	Elk Creek	B1	FGH	0.00002	2.55
2011	10	5	20	0	51.09	38.9645	-107.4870	0.86		1.9	Elk Creek	B1	FGH	0.00009	2.46
2011	10	6	16	31	39.29	38.9528	-107.4968	0.26		2.0	Elk Creek	C1	WTM	0.00002	3.52
2011	10	7	0	55	24	38.9647	-107.4850	0.90		1.7	Elk Creek	B1	FGH	0.00012	2.52
2011	10	7	16	52	17.3	38.9647	-107.4857	0.85		1.7	Elk Creek	B1	FGH	0.00010	2.51
2011	10	8	0	45	55.92	38.9647	-107.4870	0.74		1.9	Elk Creek	B1	FGH	0.00003	2.48
2011	10	8	0	46	1.47	38.9660	-107.4890	0.64		1.1	Elk Creek	B1	FGH	0.00005	2.54
2011	10	8	2	22	36.77	38.9652	-107.4867	0.85		1.8	Elk Creek	B1	FGH	0.00002	2.52
2011	10	8	3	35	54.47	38.9648	-107.4858	0.84		1.8	Elk Creek	B1	FGH	0.00010	2.52
2011	10	9	6	16	15.41	38.9622	-107.4873	0.60		2.0	Elk Creek	B1	FGH	0.00097	2.28
2011	10	9	17	3	34.88	38.9608	-107.4830	0.00		1.7	Elk Creek	B1	FGH	0.00011	2.29
2011	10	9	18	17	19.56	38.9627	-107.4783	0.00		2.5	Elk Creek	C1	FGH	0.00180	2.54
2011	10	9	22	53	40.46	38.9658	-107.4858	0.72		1.7	Elk Creek	B1	FGH	0.00003	2.60
2011	10	9	23	34	57.81	38.9637	-107.4842	0.76		1.8	Elk Creek	B1	FGH	0.00008	2.46
2011	10	10	3	2	19.15	38.9662	-107.4863	0.93		1.7	Elk Creek	B1	TCR	0.00001	3.13
2011	10	10	17	39	43.29	38.8773	-107.4285	2.05		1.8	West Elk	B1	No strong motion data		
2011	10	10	18	50	45.64	38.9658	-107.4863	0.97		1.8	Elk Creek	B1	FGH	0.00005	2.58
2011	10	10	20	52	49.16	38.9613	-107.4863	0.00		1.7	Elk Creek	B1	FGH	0.00002	2.24
2011	10	10	22	28	21.09	38.9575	-107.4907	0.00		2.0	Elk Creek	B1	FGH	0.00011	1.88
2011	10	11	21	20	35.57	38.9653	-107.4862	0.89		1.9	Elk Creek	B1	FGH	0.00005	2.55
2011	10	11	22	30	10.19	38.9618	-107.4852	0.00		1.8	Elk Creek	B1	FGH	0.00002	2.31
2011	10	12	4	29	30.84	38.9603	-107.4817	0.00		1.7	Elk Creek	B1	FGH	0.00004	2.30
2011	10	12	18	12	13.09	38.9652	-107.4862	0.96		2.0	Elk Creek	B1	FGH	0.00007	2.53
2011	10	13	15	50	46.12	38.9652	-107.4877	0.77		1.8	Elk Creek	B1	FGH	0.00002	2.50
2011	10	13	16	4	7.62	38.9633	-107.4835	0.72		0.0	Elk Creek	B1	No strong motion data		
2011	10	13	16	4	52.57	38.9645	-107.4850	0.87		1.7	Elk Creek	B1	FGH	0.00005	2.51
2011	10	13	20	43	46.69	38.9702	-107.4908	0.57		1.7	Elk Creek	C1	MCD	0.00004	9.94
2011	10	13	21	52	3.6	38.9652	-107.4872	0.88		1.9	Elk Creek	B1	FGH	0.00005	2.51
2011	10	14	0	3	4.13	38.9245	-107.5490	0.00		1.7	Bowie	B1	FGH	0.00007	2.66
2011	10	14	0	6	47.07	38.9633	-107.4850	0.79		1.7	Elk Creek	B1	FGH	0.00009	2.42
2011	10	14	20	8	29.33	38.9628	-107.4822	0.83		1.7	Elk Creek	C1	FGH	0.00004	2.45
2011	10	14	20	40	46.16	38.9658	-107.4888	0.75		1.8	Elk Creek	B1	FGH	0.00008	2.53
2011	10	14	21	46	43.11	38.9660	-107.4887	0.84		1.7	Elk Creek	B1	FGH	0.00002	2.55
2011	10	15	18	21	56.68	38.9632	-107.4848	1.15		1.7	Elk Creek	B1	TCR	0.00003	3.39
2011	10	16	2	37	38.11	38.9668	-107.4877	0.90		1.8	Elk Creek	B1	FGH	0.00006	2.64
2011	10	16	22	37	19.04	38.9665	-107.4865	0.79		1.8	Elk Creek	B1	FGH	0.00003	2.64
2011	10	17	4	28	36.38	38.9273	-107.5638	0.15		1.8	Bowie	B1	WTM	0.00022	1.83
2011	10	17	12	3	2.64	38.9642	-107.4875	0.00		1.7	Elk Creek	B1	FGH	0.00003	2.42
2011	10	17	16	23	30.86	38.9552	-107.4872	0.00		1.8	Elk Creek	C1	FGH	0.00002	1.86
2011	10	17	18	15	44.78	38.9680	-107.4908	0.68		1.7	Elk Creek	B1	FGH	0.00003	2.68
2011	10	17	18	16	46.59	38.9322	-107.5793	0.44		1.7	Bowie	B1	WTM	0.00035	1.07
2011	10	17	18	44	53.61	38.9657	-107.4853	0.90		1.9	Elk Creek	B1	FGH	0.00006	2.59
2011	10	18	15	8	33.3	38.9678	-107.4892	0.88		1.7	Elk Creek	B1	FGH	0.00004	2.70
2011	10	19	5	24	16.39	38.9603	-107.4832	0.00	3.0	3.0	Elk Creek	B1	FGH	0.00563	2.26
2011	10	22	21	40	22.81	38.9605	-107.4898	0.88		1.8	Elk Creek	B1	BWK	0.00013	3.96
2011	10	25	5	42	35.83	38.9347	-107.4787	0.50		1.8	South of Elk Cr	B1	BWK	0.00010	2.26
2011	11	1	21	12	39.55	38.9640	-107.4932	0.67		1.7	Elk Creek	B1	FGH	0.00008	2.29
2011	11	4	19	50	43.13	38.9645	-107.4837	0.95		1.9	Elk Creek	B1	BWK	0.00011	4.44
2011	11	4	20	56	20.84	38.9570	-107.4772	0.37		2.8	Elk Creek	C1	TCR	0.00007	4.07
2011	11	5	17	56	13.47	38.9538	-107.5585	0.85		1.9	Bowie	B1	FGH	0.00018	1.01
2011	11	7	20	4	42.16	38.9618	-107.4853	0.75		1.8	Elk Creek	B1	BWK	0.00014	4.15
2011	**11**	**7**	**22**	**48**	**43.66**	**38.9653**	**-107.4865**	**0.90**		**2.0**	**Elk Creek**	**B1**	**BWK**	**0.00096**	**4.49**
2011	11	9	4	56	43.83	38.9647	-107.4855	0.92		2.3	Elk Creek	B1	FGH	0.00006	2.51
2011	11	10	11	40	50.18	38.9167	-107.5543	0.00		1.8	Bowie	C1	BWK	0.00003	1.43
2011	**11**	**12**	**12**	**15**	**5.02**	**38.9208**	**-107.4548**	**2.38**		**2.0**	**West Elk**	**B1**	**MCD**	**0.00065**	**4.49**
2011	11	13	3	46	42.23	38.9167	-107.4633	0.00		1.8	West Elk	C1	MCD	0.00022	3.99
2011	11	13	17	18	16.82	38.9627	-107.4860	0.74		2.0	Elk Creek	B1	FGH	0.00008	2.35
2011	11	14	17	29	39.93	38.9658	-107.4857	0.83		1.7	Elk Creek	C1	FGH	0.00002	2.60
2011	11	16	17	3	33.98	38.9648	-107.4872	0.90		2.2	Elk Creek	B1	FGH	0.00004	2.49
2011	11	18	18	48	43.13	38.9648	-107.4867	0.94		2.0	Elk Creek	C1	MCD	0.00014	9.34
2011	11	19	3	20	22.49	38.9560	-107.4858	0.32		1.8	Elk Creek	C1	FGH	0.00005	1.94
2011	11	19	15	18	55.15	38.9553	-107.4900	0.00		1.7	Elk Creek	C1	FGH	0.00004	1.78
2011	11	19	16	28	50.98	38.9640	-107.4842	0.95		1.8	Elk Creek	B1	BWK	0.00013	4.38
2011	12	3	11	49	5.37	38.9567	-107.4775	0.00		1.7	Elk Creek	C1	BWK	0.00012	3.79
2011	12	4	0	42	41.55	38.9283	-107.5507	1.85		1.7	Bowie	C1	BWK	0.00005	0.51
2011	**12**	**13**	**19**	**27**	**42.02**	**38.9780**	**-107.4832**	**4.68**		**1.7**	**Elk Creek**	**C1**	**BWK**	**0.00011**	**5.83**



URS	Project No. 26817412 Mountain Coal Co. West Elk Mine Colorado	SEISMIC STATION LOCATIONS, PERMIT AREAS, AND MINE LOCATION MAP	Figure 1



Stations

Permit Area

Area of active mining Q4

N

0 1.5 3 Kilometers

0 1.5 3 Miles

Magnitudes

- No Magnitude or < 1.7
- 1.7 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0

Note: Tectonic events highlighted in yellow.

URS	Project No. 26816326 Mountain Coal Co. West Elk Mine Colorado	RELOCATED SEISMICITY 1 OCTOBER TO 31 DECEMBER 2011	Figure 2