35th International Conference on Ground Control in Mining

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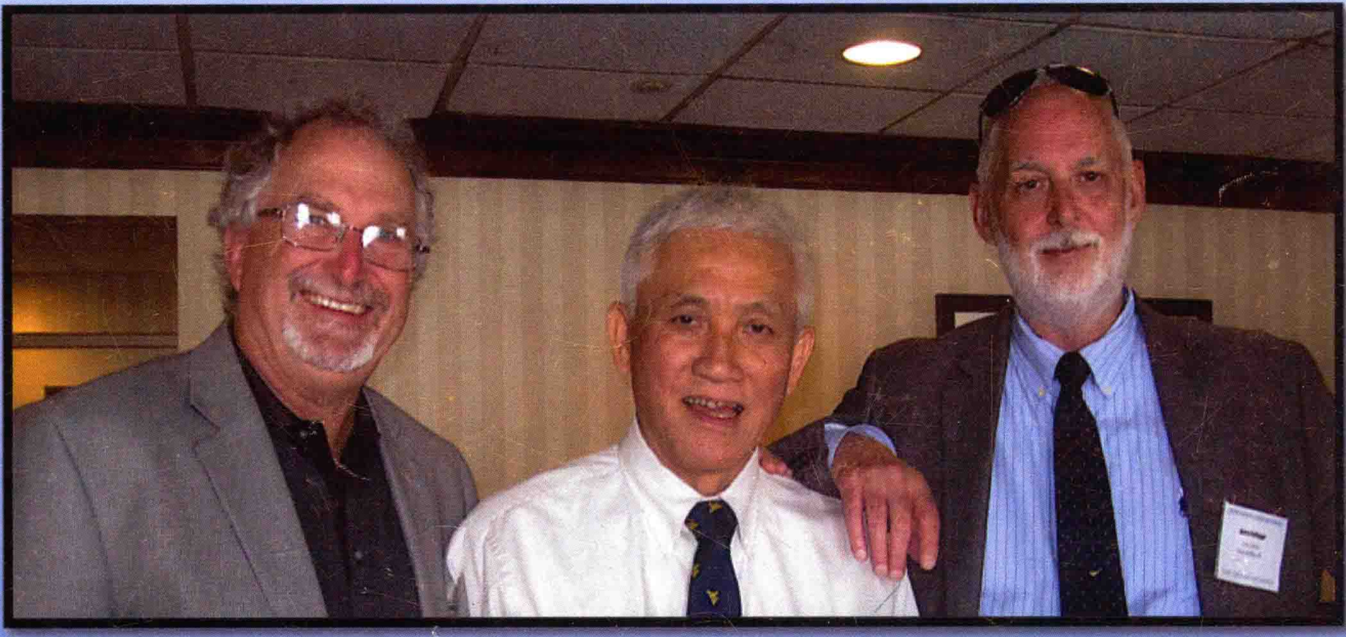

Don't blink – 35 years go by faster than you think!

July 26 – 28, 2016

Lakeview Resort, Morgantown, WV

Proceedings
35th International Conference on Ground Control in Mining

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Syd S. Peng Ground Control in Mining Award

Dr. Xie-Xing Miao is the 2015 recipient of the Syd S. Peng Ground Control in Mining Award.

Dr. Miao is a professor of mining engineering at the China University of Mining and Technology (CUMT). He is the vice president of CUMT in charge of graduate program. He is also the director of State Key Laboratory, Geomechanics and Deep Underground Engineering. He is an executive of Chinese Society for Rock Mechanics and Engineering, and editor-in-chief of "International Journal of Mining Science and Technology" and "Journal of Mining & Safety Engineering".

Since 1982, Prof. Miao has been performing research and development work in basic theory, key technology and equipment design related to coal mining in China, and has made enormous contribution to solve the problems associated with coal mining under buildings, roads, and water bodies. Based on his long-term in-depth research on the characteristics of strata movement and failure and its controlling methods in longwall mining, he solved the key technical problems associated with coal mining with backfilling. Subsequently, he developed and successfully implemented the technology of fully mechanized solid backfilling coal mining method in China. This technology not only allows the coal reserves under buildings/villages, roads/railroads, and water bodies to be mined safely and efficiently, but also uses the solid wastes as backfilled materials for protection of water, land and ecological environment.

Currently, the backfilling technology developed by Prof. Miao has been adopted by 23 longwall mines in as many panels in six major coalfields of China, with a total annual production in excess of 40 million metric tons. It has achieved significant economic, social and environmental benefits, and made important contribution to the development of backfilling technology as well as protection of environment in mining areas.

In China, Prof. Miao is well recognized for research achievements on backfilling mining methods and roof bolting monitoring. He has received one National Award for Technological Invention, two National Awards for Science and Technology Progress, and six Provincial and Ministerial Level Scientific and Technological Progress Awards, and twelve items of international and domestic invention patents. Prof. Miao also published six monographs and more than 160 journal papers.

About The Syd S Peng Ground Control in Mining Award: The purpose of the award is to provide recognition to individuals that have demonstrated technical and scientific excellence in advancing the understanding of ground control technologies or approaches by either publication or direct applications in the mining industry.

Syd S. Peng Ground Control Scholarships

As a part of the Syd S. Peng Ground Control in Mining Award - an undergraduate and/or graduate scholarship, or scholarships, will be awarded annually to encourage the development of ground control engineers. The scholarship will be a minimum of $5,000 (U.S.) and provided in a single payment to the recipient by January 1 (so the funds are available for the Spring Semester).

The 2015 scholarships were awarded and the recipients were recognized during the banquet at the Annual SME Meeting held in Denver, Colorado. The 2015 recipients were:

- Rahul Thareja, University of Nevada-Reno
- Anna Perry, Queens University

Awards presented by Dennis Bryan, SME Foundation President

Kazem Oraee Scholarship for Mining

The **Kazem Oraee Scholarship for Mining** award is to promote underground mining engineering and more specifically, the ground control discipline. Recent trends indicate that a shortage of competent ground control engineers may exist if this trend is allowed to continue. To help remedy the situation and promote the ground control engineering discipline, an undergraduate OR graduate scholarship, will be awarded annually at the International Conference on Ground Control in Mining (ICGCM) to encourage the development of ground control engineers. The scholarship recipient will receive $5,000 (US) provided in a single payment and a commemorative certificate/statue.

The 2015 winner was Chris Newman. Chris recently completed his Master's degree at West Virginia University, studying under the direction of Dr. Keith Heasley. His research topic was "Development of an Online User's and Training Manual for LaModel". This program has been widely adopted as a ground control design tool and Chris worked with Dr. Heasley to transform the capabilities to an online system. The comprehensive electronic user's manual and training modules provide a singular source for LaModel reference and training materials. The user's manual allows one to quickly access information on the installation, operation, and troubleshooting procedures of the LaModel program through the incorporation of detailed documentation, software simulations, presentations, and related academic articles. Following graduation from West Virginia University, Chris has moved on to the University of Kentucky to pursue his Ph.D. in mining engineering.

Shown is the Tom Barczak and Steve Tadolini presenting the award to Sean Warren.

ICGCM – The Best of Ground Control in Mining

The Best of Ground Control was held at the 2016 SME Annual Meeting & Exhibit on February 17, 2016, Phoenix, AZ. This is a standing SME session at the Annual Meetings in the Coal & Energy Division. The technical papers were selected from the 34th International Conference of Ground Control in Mining (ICGCM 2015). This was an exceptional line-up and very well attended at the conference. The papers are selected during the conference based on technical originality and merit and the quality of the presentation. In keeping with the original vision of Dr. Syd S. Peng for the conference, a diverse group of selections are sought from industry, academia, manufacturers, consultants and government.

(from left to right) Syd Peng (West Virginia University), Robin Oldam, (GMS Mine Repair and Maintenance), Ihsan Tulu (NIOSH Office of Mine Safety and Health Research, Pittsburgh, PA), Michael Murphy (NIOSH Office of Mine Safety and Health Research, Pittsburgh, PA), Eric Poeck (Colorado School of Mines, Golden, CO), Michael Gauna (Mine Safety and Health Administration, Pittsburgh, PA), Heather Lawson (NIOSH Office of Mine Safety and Health Research, Spokane, WA), Steve Tadolini (Orica Ground Support)

Harrison County Mine
Courtesy of Murray Energy

Cumberland Mine
Courtesy of Alpha Natural Resources

Leer Mine
Courtesy of Arch Coal

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Chinese Mining Practices and Solutions

Structural Geological and Stress Controls on Natural Gas Inrushes in Southern West Virginia Longwall Coal Mines

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INTRODUCTION

On April 5, 2010 a massive dust-fueled explosion at a longwall mine in southern West Virginia claimed the lives of 29 miners. The mine had experienced large gas inrushes from the floor on two known previous occasions, and natural gas was found emanating from floor fractures behind the longwall shields after the explosion, indicating a likely fuel source for the initial ignition. In succeeding months, another longwall mine operating in the same seam 15 miles away encountered smaller inflows of natural gas that halted production from two different longwall faces. Production was halted at a third longwall mine, 30 miles south of the first, in May 2011, when explosive levels of methane were detected inby the longwall face on the headgate. The same mine was evacuated on March 20, 2014 when a series of floor gas feeders were encountered on the longwall face. A literature review indicated that there has been little documentation or description of these events, and that their size and frequency are unknown. The most significant floor gas inrushes in the United States are believed to have been associated with longwall mining in the Pocahontas No. 3 Seam of western Virginia, in which an estimated 5.8 x 10^7 ft^3 of natural gas was expended from a floor feeder on the longwall face over a two-week period (Aul, pers. comm.).

A variety of mechanisms and circumstances are associated with methane emanations from underground mines. Hyman (1987) defined an outburst as a violent, simultaneous release of gas and comminuted rock material into a working face or the interior of a borehole, and indicated that certain soft or fractured coals have a propensity for outburst based on gas desorption rates. In this mechanism, reservoirs of autogenic gas hosted in pockets of soft, crushed coal surrounded by harder coal are released suddenly as confining stress is removed by mining. Hyman (1987) also suggested that highly stressed, relatively gassy coal that is penetrated by mining-induced fractures could be outburst-prone. Clayton et al. (1993) and Ulery (2008) recognized the importance of faults as potential conduits for gas from adjacent strata into coal mines, and suggested that biogenic gas trapped in adjacent strata could migrate into mined coal seams due to a pressure differential. Ulery (2008) distinguished between an outburst and a blower, the latter defined as an event expending a large amount of gas over an extended time period, most often emanating from underlying strata, but without expulsion of coal or rock. Methane feeders are further defined as a subset of blowers that continually expend gas over a long period of time but at a lower rate. Many of the mechanisms discussed by Ulery (2008) relate to geologic features that can impound gas within the seam, releasing a voluminous amount when mining breaches the clastic dike, fault gouge, or other geologic structure that had restricted and compartmentalized coalbed methane migration. Thus, the events discussed in this paper can be described as blowers and feeders. However, detailed geological observations of the three longwall mines discussed in this paper appear to indicate a mechanism that is different from those described by Hyman (1987) or Ulery (2008), in that they did not involve coalbed-sourced gas, and the reservoirs were not hosted by coal seams.

This paper will describe the circumstances associated with gas blowers and feeders that occurred at three longwall mines in southern West Virginia, and propose a release mechanism and associated geologic model that is based on the results of geologic mapping, geochemical analyses, and stress analyses. Based on the proposed mechanism, strategies to avoid triggering the gas releases will be discussed. The geologic environment and gas release mechanism suggests that longwall mines operating in the Eagle and Pocahontas No. 3 Seams may continue to encounter sudden, voluminous releases of floor gas, and should be prepared to either avoid them or mitigate their effects.

BACKGROUND

Mining and Inrush History

Two of the study mines extract coal from the Eagle Seam, hosted in the Lower Pennsylvanian-aged Pottsville Group, while the third study mine extracts coal from the Pocahontas No. 3 Seam, also hosted in the Pottsville Group (Figure 1). The first longwall mining in the Eagle Seam was conducted in the early 1950s (Anon., 1951; Thomas, 1965). In succeeding years, longwall mining in the Eagle Seam expanded in a cluster, finally including the mine herein referred to as Mine 1. The only longwall mine operating in the Eagle Seam outside of this cluster is Mine 2, located 15 miles north (Figure 1). There have been several longwall mines developed in the Pocahontas No. 3 Seam, of western Virginia, but only one such mine, referred to as Mine 3, in southern West Virginia.

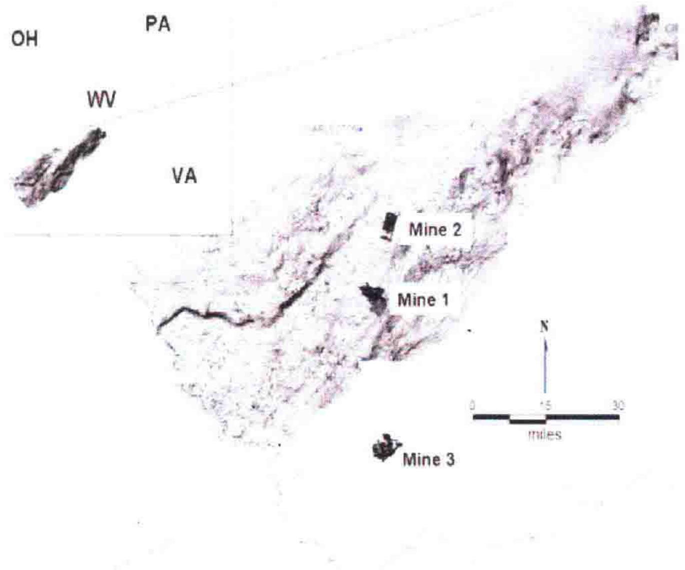

Figure 1. Location of the three longwall mines described in this paper in relation to the extent of the Eagle Seam, represented by pattern of structure contours, from West Virginia Geologic and Economic Survey GIS data.

Mine 1 experienced an ignition and related explosion on its first longwall panel in 1997, when the longwall face was beneath 820 feet of overburden while undermining a gob/solid boundary in the Powellton Seam, located 180 feet above (Ross, 1997). The circumstances of this event are not well documented with respect to the presence of floor gas, although one witness recalled a stale kerosene smell prior to noticing an orange glow in the tailgate behind the shields. The mine experienced its first known gas blower in 2003, when the longwall face was beneath 1,175 feet of overburden while mining beneath regular room-and-pillar workings in the overlying Powellton Seam. The mine experienced a second gas blower in 2004, on the subsequent panel, when the face was beneath 1,155 feet of overburden while undermining a retreat-mined panel that represented a gob/solid boundary in the overlying Powellton Seam. Both the 2003 and 2004 events were described as being preceded by loud thumps that were believed by mine staff to represent breaking sandstone, and characterized by an inrush of gas from floor fractures developed behind the longwall shields at mid-face for a length of up to 240 feet, and accompanied by noise likened to that from a jet engine. Each event resulted in the mine being idled for several days while the gas was diluted by increased ventilation. On April 5, 2010 the longwall face was beneath 1,075 feet of overburden while undermining two rows of remnant pillars flanked by retreat-mined gob in the overlying Powellton Seam. Upon re-entering the mine after the explosion, several irregular fractures emanating gas were discovered directly behind the shield pontoons near the tailgate of the longwall face.

The first known instance of floor gas that resulted in cessation of mining at Mine 2 occurred in May 2010, when the longwall face was beneath approximately 1,000 feet of overburden. In this instance, a fracture zone approximately 50 feet long was located behind the shield pontoons on the tailgate side of mid-face, with gas release accompanied by a roar and foamy water that briefly covered the floor between the shield pontoons and the face before seeping back into the floor. The fracture zone was still producing a gurgling noise from gas seeping through formation water on the following day, although face ventilation effectively diluted the gas. Initially, the gas blower resulted in near-explosive levels of methane accumulating in pockets where the shields locally restricted airflow across the face, although there was apparently insufficient gas to trigger the longwall equipment's methane monitors. The same panel experienced a second floor feeder a few weeks later when gas was produced from a fracture in the tailgate itself, where the face was adjacent to longwall gob of the previous panel under tailgate loading conditions. The panel had also recently resumed mining on a 'jump panel' (e.g. when the longwall face equipment is removed from the current panel and mining is resumed on the other side of a feature adverse to mining) to avoid sandstone roof, defining a geometry in which the width of the longwall face was roughly equal to the length of the gob. The next floor gas expulsion was experienced in October 2010 when the mine began longwall production from the first panel in a new district. That event occurred when the longwall face was beneath approximately 1,000 feet of overburden, and the face width was roughly equal to the length of the gob. It was reported that two previous floor gas events had been encountered well before the 'squared up' geometry had been defined. The October event was associated with floor gas emanating from fractures that developed beneath the longwall shearer's tail drive, releasing an explosive-range mixture that caused the equipment's methane monitor to cut power to the shearer. The fracture continued to release gas for several days, and despite increased ventilation, explosive-range mixtures accumulated adjacent to the rock plate at the tailgate shield until the gas reservoir finally bled off.

Mine 3 experienced a floor gas event in May 2011 in association with a mining geometry that was nearly identical to that of Mine 2. When the first panel of the new district had mined to a point such that the gob length was approximately equal to the face width, an explosive mixture of methane was detected in the headgate inby the face. On March 20, 2014 the mine was evacuated when a series of floor feeders were encountered on the longwall face, issuing gas that overwhelmed the face ventilation. Discussion with a former mine employee indicated that a major gas blower had been encountered in what was also the first panel of a previous new longwall district in the same mine, when the gob length was approximately equal to the face width.

Discussion of Natural Gases

Primary gases originate from bacterial respiration (biogenic) and thermal alteration of liquid or solid organic precursors (thermogenic) (Claypool et al., 1978; Schoell, 1983). Samples of coal collected from various seams by Kim (1973) contained gas that was characterized by generally greater than 90% methane and 1.0-1.5% ethane, with negligible amounts of heavier gaseous hydrocarbons. Similarly, experiments conducted by Kim (1974) involving the collection of gas desorbed from coal samples revealed domination (99.5%) by methane and ethane, with only trace amounts of higher hydrocarbons. Scott (1993) reports that average coalbed gas contains 93.2% methane, 3.1% carbon dioxide, 2.6% wet gases (i.e. C_{3+} hydrocarbons) and 1.1% nitrogen. Natural gas is generated from organic matter throughout the burial history of sedimentary rocks. The gas formed during each of these stages has a characteristic chemical composition and stable carbon isotope ratio for methane. Biogenic gas is predominantly methane that is isotopically light ($\delta^{13}C$ = -90 to -55‰). Methane originating during the thermal generation of petroleum is always accompanied by ethane and heavier hydrocarbons, and is isotopically heavier ($\delta^{13}C$ = -55 to -35‰).

Samples of gas were collected from the three study mines by members of MSHA's Roof Control and Ventilation Divisions using an SKC permissible dust pump and 1-liter cali-bond sample bags. Floor gas was collected by inserting a probe into open floor fractures and packing the crack surrounding the probe to obtain the greatest concentration of gas. Atmospheric dilution was minimized by using an Industrial Scientific MX6 multi-gas monitor gas detector to ensure that methane readings were near 100% concentration before using the SKC pump to draw a sample. Where samples were drawn from feeders in standing water, a capped 10-inch-diameter PVC pipe was emplaced above the bubbling feeder as a sampling chamber to allow accumulation of gas. The gas was then drawn into the sample bag by means of a line fitted to the top of the chamber, again using the MX6 to ensure high methane concentration.

Samples of gas were collected from several locations at Mine 1, including floor fractures behind the shields (90.15% methane; 5.99% ethane; 2.68% propane; 0.71% combined butanes; 0.12% combined pentanes, and; 0.04% hexane and heptane) on the tailgate side of the longwall face, and from development sections that hosted gas feeders bubbling up through standing water three-quarters of a mile from the longwall face. Samples of gas were collected from Mine 2 at the July and October, 2010 events (90.14% methane; 4.18% ethane; 1.49% propane; 0.84% combined butanes; 0.46% combined pentanes; 0.39% hexane and heptane). Samples of gas were collected from Mine 3 in June, 2011, from exploratory holes drilled into the gob, indicating a gas composed of 95.9% methane, 3.6% ethane, 0.3% propane, 0.07% combined butanes, 0.02% combined pentanes, and 0.02% hexane and heavier hydrocarbons, normalized to 100% after calculating out contaminating air. It should be noted that this last sample is likely to have been diluted because it was collected from a bore hole that sampled a large gob area, rather than a pure gas source such as the previous samples. Even samples collected from pure gas feeders experienced dilution because the sample pump capacity exceeded the natural flow rate of the gas feeder, thereby drawing in the ambient atmosphere. Samples from Mine 3 were also collected from the March 2014 event (97.37-97.57% methane, 2.26-2.45% ethane, 0.129-0.144% propane, 0.23-0.027% combined butanes, 0.004-0.005% combined pentanes, and 0.002-0.003% hexane).

All samples were subjected to analysis by a gas chromatograph at a commercial laboratory in order to determine the fractions of hydrocarbons, in addition to being subjected to analysis by mass spectrometry in order to determine the ratios of stable isotopes for comparison with published discrimination diagrams. Values of $\delta^{13}C$ and δD, in combination with the ratio of methane to combined ethane and propane were plotted on a discrimination diagram showing fields for various natural gas sources, including a field associated with humic (equivalent to Type III kerogen) coal (Whiticar, 1996). The diagram indicates that the gas samples collected from the longwall face of Mine 1 and all samples collected from Mines 2 and 3 represent thermogenic gas that was not derived from a humic coal (Type III kerogen) source (Figure 2). These samples are interpreted to represent natural gas that must have been derived from some deep organic source, rather than coal-derived methane. However, samples of gas collected from small floor feeders in the development sections of Mine 1, which are interpreted to represent coalbed methane derived from the underlying Little Eagle Seam because they are characterized by an absence of higher hydrocarbons, do not have isotopic signatures indicative of biogenic methane or a Type II kerogen source. Instead, the small floor feeders are interpreted to represent mixing of gases. Only a sample of gas obtained from desorbed coal on Mine 1's longwall face represents microbial gas.

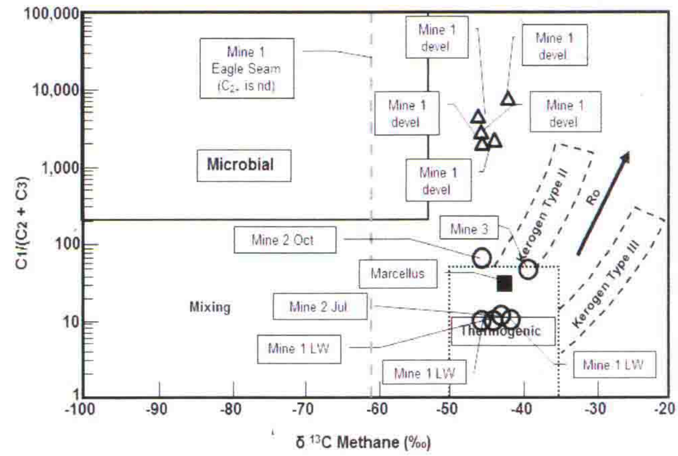

Figure 2. Discrimination diagram showing fields of gas from microbial and thermogenic sources, based on comparison of C1, C2, and C3 hydrocarbons (ratio of methane to combined ethane and propane), compared to δ 13C for methane (‰). Diagram modified from Whiticar, 1999). Open circles indicate samples that contain C2+ hydrocarbons; open triangles indicate samples with little or no C2+ hydrocarbons. Black square indicates samples that were obtained from an actively producing gas well in the Marcellus Shale near the study area. Samples from Mine 1 were collected from the coal seam itself (Eagle Seam), from development sections (devel.), and from the longwall face (LW). Samples from Mine 2 were collected from a July 2010 event (Jul.) and from an October 2010 event (Oct.) that occurred on different longwall faces. Samples from Mine 3 were collected from the longwall face in March 2014.

STRUCTURAL GEOLOGY

Mine 1

Geologic mapping was conducted in available gateroad exposures by MSHA's Roof Control Division following Mine 1's 2004 floor gas blower occurrence, identifying a series of slickensides concentrated in a zone that projected along a diagonal line 700-800 feet west of both the 2003 and 2004 floor gas areas (Figure 3). The possibility that a linear structural trend might be defined by the blower locations was subsequently explored in detail when it became apparent that if the slickenside trend were projected along strike, it would intersect the longwall face at the time of the April 5, 2010 explosion.

Geologic mapping was conducted on the surface where old contour mine strip benches and an active surface mine afforded outcrop. Underground geologic mapping was conducted in Mine 1, as well as in workings developed in the overlying Powellton Seam (located 180 feet above) and Coalburg Seam (located 820 feet above). Based on underground observations conducted in 2004, extensive surface and underground observations conducted in 2010, and the locations of longwall faces that were terminated for unknown reasons or encountered blowers or a face ignition,