

DIRECTIONAL DRILLING TECHNIQUES FOR EXPLORATION IN-ADVANCE OF MINING

Stephen J. Kravits

Jeffrey J. Schwoebel

Resource Enterprises, Inc.

ABSTRACT

In-seam directionally drilled horizontal boreholes have provided effective solutions in underground coal mines for methane and water drainage and inherently provide an excellent tool for coalbed exploration. Emphasis of the paper will be placed on demonstrating where directionally drilled methane drainage boreholes have identified rapid changes in coalbed elevation, coalbed thickness and faults. Specific directional drilling and coring procedures for exploration in-advance of mining are reviewed. Other directional drilling applications include in-mine horizontal gob ventilation boreholes, identification of abandoned workings, and water drainage boreholes. Applications of the techniques described herein have stimulated considerable interest within the underground coal mining community.

INTRODUCTION

Accumulations of methane gas, water and adverse geologic conditions often times plague mine operators. These problems can result in significant delays in coal production and cause a hindrance to coal mine safety. Furthermore, to stay competitive in the coal market, mine operators must apply cost effective solutions to these problems.

Ventilation is not always adequate to maintain coalbed methane and gob gas emissions within mandatory limits. Directionally drilled long horizontal in-seam boreholes have been used by several companies to recover methane in-advance of mining. Methane concentrations have been significantly reduced and has improved mining productivity at these operations. Furthermore, the sale of recovered methane has occurred at several mines (1,2,3).

Geologic anomalies, (e.g., rapid changes in elevation, faults or washouts, sandstone channels, faults, igneous dikes, etc.) can adversely effect mining productivity and cause changes in mine planning. To date, mine operators typically use conventional coring and geophysical coalbed exploration techniques. Horizontal boreholes in-advance of mining can quantitatively identify these geologic anomalies.

IN-MINE DIRECTIONAL DRILLING

Equipment

A permissible longhole drill with thrust capabilities of at least 20,000 pounds is used to supply bit weight by maintaining hydraulic pressure on the drill rods. A downhole motor is used to directionally drill the boreholes. Downhole motors are positive-displacement hydraulic motors that convert hydraulic horsepower to mechanical horsepower by providing bit rotational speed and torque, without rotating the drill rods. The capability of simultaneously maintaining vertical and lateral borehole trajectory is made possible due to the non-rotation of the drill rods.

Vertical and lateral trajectory of the borehole is controlled by using a bent housing on the downhole motor. During directional drilling, the bent housing exerts a force on the bit in the opposite direction that it is oriented. This is referred to as tool face direction (Figure 1). Borehole trajectory is achieved by orienting the bent housing in the appropriate tool face direction. Tool face direction can be oriented to drill in any direction. Borehole inclination, bearing and tool face direction are monitored using a permissible survey tool. The inclination and bearing are used to calculate borehole elevation and coordinates which are plotted to maintain desired trajectory.

Techniques

During the directional drilling of horizontal boreholes in coal, the roof and floor are periodically intercepted. This is done intentionally and unfortunately, at times, involuntarily. The roof and floor are identified by sampling drill cuttings and changes in drilling parameters (e.g., thrust increases in non-coal formations). The borehole elevation is calculated and plotted from borehole surveys and correlated with these "out-of-coal" intercepts to accurately determine coalbed elevation.

When the roof or floor are encountered, drilling can be continued by steering the borehole towards the coalbed. This is accomplished by relocating the downhole motor back into a coal zone and initiating a sidetrack. The purpose of a sidetrack is to start a "new" borehole below the previous borehole. The new borehole is then resumed by changing trajectory from the abandoned portion of the borehole to avoid intercepting the roof or floor.

The following case study describes a methane drainage project where long in-seam boreholes were used to degasify coal reserves far in-advance of mining. A long borehole also identified a geologic anomaly and allowed the coal operator to modify mining plans, as appropriate.

PASTA DE CONCHOS MINE PROJECT

In 1991, Resource Enterprises, Inc. ("REI") directionally drilled five (5) long (>2,000 feet) in-seam horizontal methane drainage boreholes into virgin blocks of coal in-advance of mining development at Carbonifera de Nueva Rosita, S.A. de C.V.'s ("CNR") Pasta de Conchos Mine, near Nueva Rosita, Coahuila, Mexico. The degasification approach, shown in Figure 2, reduced methane concentration in the

return air course from greater than 1.0 percent to less than 0.8 percent. Peak production from the five (5) boreholes reached 1.6 MMcfd (4).

During the directional drilling of borehole CNR-#2-NW in the ten (10) foot thick Double coal seam, coalbed elevation changed dramatically and the specific location of a fault was identified. Vertical coreholes, spaced about 1,500 feet apart, indicated a fault was present with about thirty (30) feet vertical displacement. However, the exact location of the fault could not be located. The following explains how the fault was identified.

CNR-#2-NW intercepted the roof at a depth of 1,410 feet. A sidetrack was initiated and intercepted the roof again, however, five (5) feet sooner at an elevation several feet below where it had been previously intercepted (Figure 3). A second sidetrack was completed in anticipation that the coalbed was down-dipping very steeply. Surprisingly, the floor was intercepted at a depth of 1,392 feet, about five (5) feet below where the roof had been intercepted during the first sidetrack. At this point, the sidetracks identified that the coalbed thinned to about five (5) feet. CNR was convinced that the fault had been intercepted, and terminated the borehole.

Additional exploration sidetracks shown in Figure 3, would have conclusively determined that a fault had been intercepted. Additional sidetracks could have also been completed to intercept the fault at a different bearing to determine fault orientation. CNR immediately changed mining plans, as appropriate, and were satisfied with the degasification and exploration benefits derived from the borehole. Furthermore, eventual mining of #7 gallery confirmed that the fault had been accurately identified by borehole CNR-#2-NW.

Identification of Coalbed Elevations

Elevation plots of two directionally drilled horizontal methane drainage boreholes that identified changes in coalbed elevation are shown in Figure 4. These methane drainage boreholes were directionally drilled and provided an accurate mechanism to determine changes in coalbed elevation and coalbed thickness. Borehole surveys were conducted on drilling intervals ranging from 20 to 100 feet. The elevation of the seven (7) foot thick Pittsburgh coal seam (EACC-#2-SE) was determined to dip upwards at about 0.5 degrees by calculating borehole elevation from surveyed borehole segments that corresponded to roof and floor markers. Ultra-long depths can be achieved as shown by borehole EACC-#2-SE drilled to 4,004 feet.

Thin coal seams can be well accessed by directional drilling techniques as shown by borehole TCC-#1A-CS. The elevation of the three (3) foot thick Lower Kittanning coal seam was determined to change from a downdip of 0.3 degrees to an updip of 0.2 degrees during directional drilling of this horizontal methane drainage borehole.

Increasing both the surveying frequency and the frequency of sidetracks to intercept the roof and floor would provide additional exploration information. As indicated during the drilling of CNR-#2-NW borehole, when a discontinuity is believed to have occurred, survey and sidetrack frequency would be increased for conclusive identification.

Coring

Conventional coring should not be attempted in a long directionally drilled borehole. Rotation of drill rods in a highly deviated borehole would likely result in drill rod separation. However, spot cores can be taken with the downhole motor at selected borehole locations. To obtain core during directional drilling, the downhole motor and drill string are removed from the borehole. The downhole motor is equipped with a two (2) foot conventional core barrel two (2) inch nominal core diameter, and installed in the borehole. After obtaining the core sample, the core barrel, downhole motor and drill string are removed from the borehole.

Other Applications

In-mine directionally drilled boreholes have been drilled to: (i) locate old abandoned workings, (ii) drain accumulations of water, and (iii) degasify gob areas. Generally, to install a water drainage borehole, a pilot borehole three (3) inches in diameter is directionally drilled 300-500 feet. The pilot hole is reamed to about six (6) inches using rotary drilling techniques and lined with steel or polyvinyl chloride plastic pipe. In certain coalbeds, reaming the borehole and cuttings removal may limit borehole length. The boreholes are equipped during and after drilling with wellheads that include safety shut-in valves to safely handle any produced gas or water.

IN-MINE GOB VENTILATION BOREHOLES

Longwall operations mining the Lower Kittanning (B) coal seam at BethEnergy Mines Inc. Cambria Slope No. 33 Mine had experienced excessive gob gas emissions resulting in costly longwall production delays and intensive drilling of numerous (up to fifteen) vertical gob ventilation boreholes.

REI conceptualized and directionally drilled nine (9) long horizontal in-mine gob ventilation boreholes totaling more than 16,000 feet over two (2) longwall panels (Figure 5) (5). These boreholes were targeted near overlying coalbeds 100 feet above the B coal seam and drilled horizontally to individual depths greater than 2,500 feet. The horizontal gob boreholes were equipped with dewatering and safety devices and connected to a vertical access well. An exhauster was used on the surface to induce a partial vacuum on the boreholes that communicated with fractures above the gob. The horizontal boreholes complemented a reduced number of vertical gob boreholes and effectively controlled gob gas emissions during the completion of both panels. Shut-in tests suggest that horizontal gob boreholes create a low pressure zone in the gob to effectively shield gas from migrating into the mine ventilation system (Figure 6).

This project demonstrated with proper placement and adequate flow capacity, horizontal in-mine gob boreholes have considerable potential where: (i) surface access is not available, (ii) tight compaction of the gob occurs, (iii) the source of the gob gas is underlying strata, and (iv) poor water drainage in the gob occurs.

Conclusions

Long in-mine directionally drilled boreholes can be a valuable exploration tool for coal mine operators. This technique provides an alternative to the following conventional and geophysical coalbed exploration techniques.

Coalbed Exploration Method	Limitations
1. Surface Drilled Exploration Coreholes	Inaccessible surface: (e.g., severe topography, urban area or surface rights not obtainable. Limited data causes numerous closely spaced coreholes and considerable interpretation.
2. In-Mine Horizontal Coreholes	Difficult to maintain corehole trajectory within coalbed. Increases with borehole length.
3. Exploration Headings	High cost of development entries.
4. In-Seam Seismic	Subjective interpretation.
5. Radio Imaging Method	Subjective interpretation.

Application of directionally drilled boreholes offer coal operators a quantitative, cost effective exploration alternative without speculation. This technique has been proven to provide solutions for methane drainage, exploration and water drainage in-advance of mining.

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Figure 1. Downhole motor side force diagram.

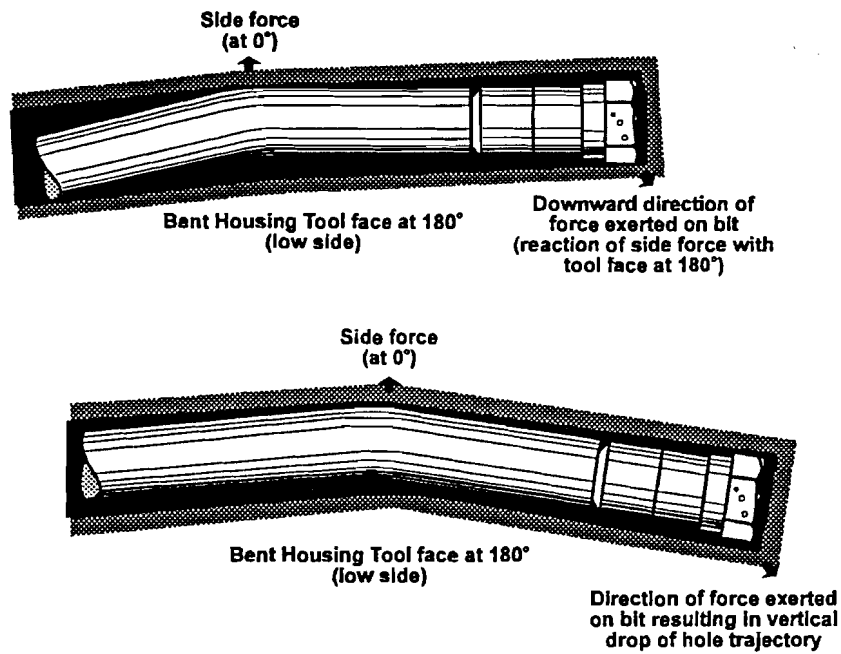
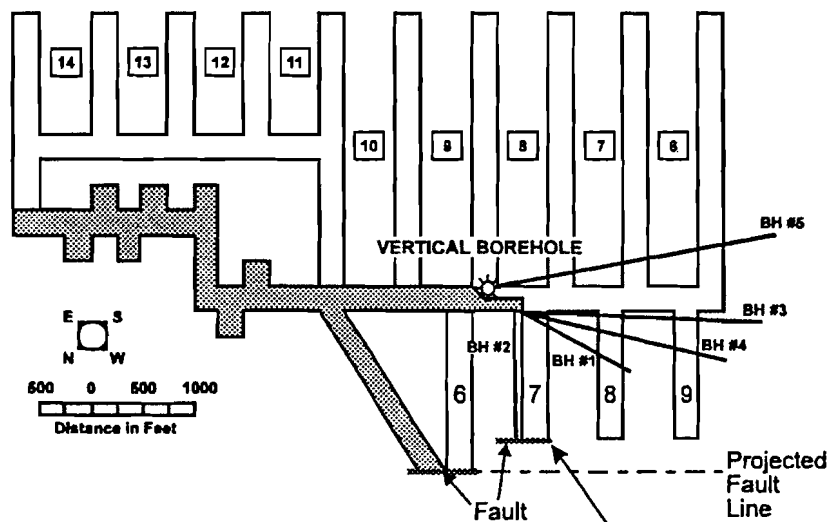


Figure 2. Carbonifera de Nueva Rosita Pasta de Conchos Mine



5 Degasification Boreholes

ID#	Length
BH#1	1,400 FT.
BH#2	1,420 FT.
BH#3	2,004 FT.
BH#4	1,886 FT.
BH#5	2,030 FT.

Fault Located By Horizontal Borehole #2

Figure 5. In-Mine Horizontal GOB Boreholes

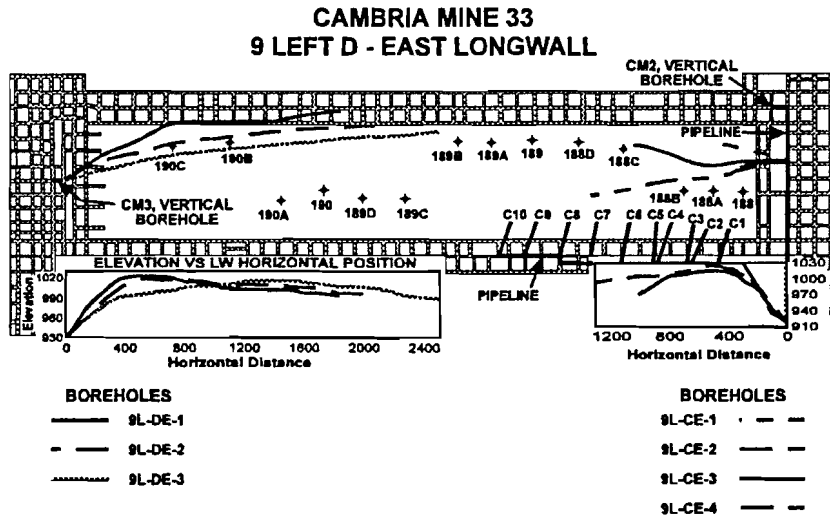
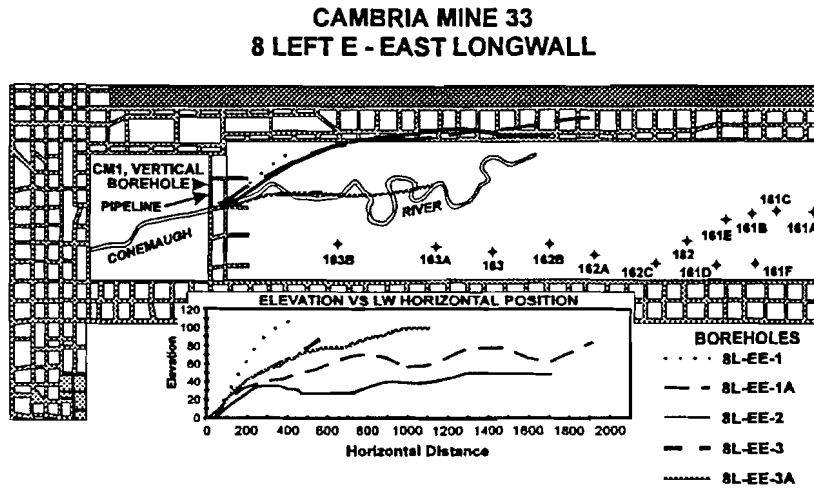


Figure 6. Low Pressure Zone Created By Horizontal GOB Boreholes

