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Finding Old Works: An Industry Search for Solutions

By

Dr. L. G. Stolarczyk, G. G. Wattley, and J. T. Duncan

Introduction

The inundation of Quecreek Mine in Pennsylvania brought considerable attention to the matter of improving underground mine safety, and the topic "which technologies are best for locating old works?" If maps of old works were accurate, there would not be such concern, but such is not the case. As an added safety factor, Pennsylvania's Governor Mark Schweiker ordered mine operators to increase barrier pillar widths from 200 to 500 feet. He assembled and empowered a Special Commission on Abandoned Mine Voids and Mine Safety, chaired by Dr. Raja V. Ramani, Professor Emeritus at Pennsylvania State University. This august group of technology and engineering investigators held several public hearings to collect testimony from industry experts on a wide range of relevant technologies from vertical and horizontal drilling to seismic to ground penetrating radar (GPR) to electromagnetic (EM) systems. The Special Commission's report was submitted to Governor Schweiker on November 15, 2002.

Additionally, the Federal Mine Safety and Health Administration (MSHA), which has been conducting an extensive investigation into the cause of the Quecreek accident, held a special informational meeting in Charleston, West Virginia, on October 28, 2002. Vendors, academicians such as West Virginia University's Dr. Syd Peng, and industry experts, such as Dr. Pramod Thakur of Consol Energy, Inc., a leader in horizontal drilling of coal-mine methane drainage, were invited to present their cases on how best to identify voids that could hold rivers of water. Well attended (over 400 people), the participants toured numerous vendor booths, listened to presentations on approaches and solutions, and engaged in informative question and answer sessions.

As reported by the media, the problem at Quecreek stemmed from reliance on an outdated mine map, a problem that concerns state and MSHA officials. How best to compensate for the risk of mine-map inaccuracies is the core challenge. Proven, yet expensive, drilling techniques are available, but so is a host of geophysical approaches such as the Radio Imaging Method™ (RIM).

Confirming Barrier Pillars

To set the context, the first line of defense to safely negotiate old works is accurate mappings of barrier pillars. In theory, if all mines were accurately mapped, confidence about the barrier pillar thickness would be of less concern. We know the craft of surveying, when appropriately applied, can provide a sufficient degree of accuracy; with a high degree of confidence the industry would secure several benefits—first and foremost, safety from underground mine flooding caused by breaching barrier pillars.

Second, with higher confidence, fewer investigative activities would be required, such as horizontal drilling at the face—a reliable, yet costly operation consuming considerable time that would otherwise be used for producing coal.

Third, the industry could reduce barrier pillar widths to 100 feet or less—an important benefit to increasing recoverable coal and reducing sterilization. While the United States has one of the largest coal reserves in the world, sterilization of this precious resource is advancing at a faster pace than we would like, and when possible, the industry needs to protect every ton.

However, as shown on the MSHA Web site, there are many situations where the accuracy of old maps is suspect. MSHA has targeted 410 mines; 203 are critical, and 207 are serious.

Vertical and Horizontal Drilling

In lieu of using a continuous miner's (CM) cutter head to find old works, when the accuracy of maps are suspect the traditional approaches to confirming the integrity of barrier pillars have been vertical and horizontal drilling techniques. A minimum barrier between the active and old works is at least 10 to 20 feet.

To assess pillar integrity from the surface, a drilling pattern needs to be laid out as depicted in Figure 1. If the rooms of the old works are 20 feet wide, the drilling needs to be in a "tight pattern" with boreholes on 20-foot centers; otherwise, one cannot ensure that, statistically speaking, old rooms have not been missed. Two problems with such an approach are that (as Frank Kendorski, of Agapito and Associates, Inc., pointed out at the Pennsylvania Special Commission hearing held October 9, 2002 in Pottsville, Pennsylvania) at $20 per foot of drilling, such a program might cost $300,000, which for many operations is a significant expense. Additionally, in Appalachia and the Western Rocky Mountains, coal operators do not have the luxury or opportunity to lay out perfect drilling patterns on 20-foot grids. Mountains get in the way; property owners are not always cooperative in allowing access to logical drill sites.

If a surface drilling effort is impractical, the second strategy to drill ahead of mining from the active works (also shown in Figure 1) can be employed. As with drilling from the surface, horizontal drilling also requires a sufficiently tight pattern to ensure that old rooms are identified, as well as the presence of water. Again, while reliable, such an approach is expensive. At $35 per foot, as well as lost production time, the search for old works with horizontal drilling techniques can also accrue several hundreds of thousands of dollars.

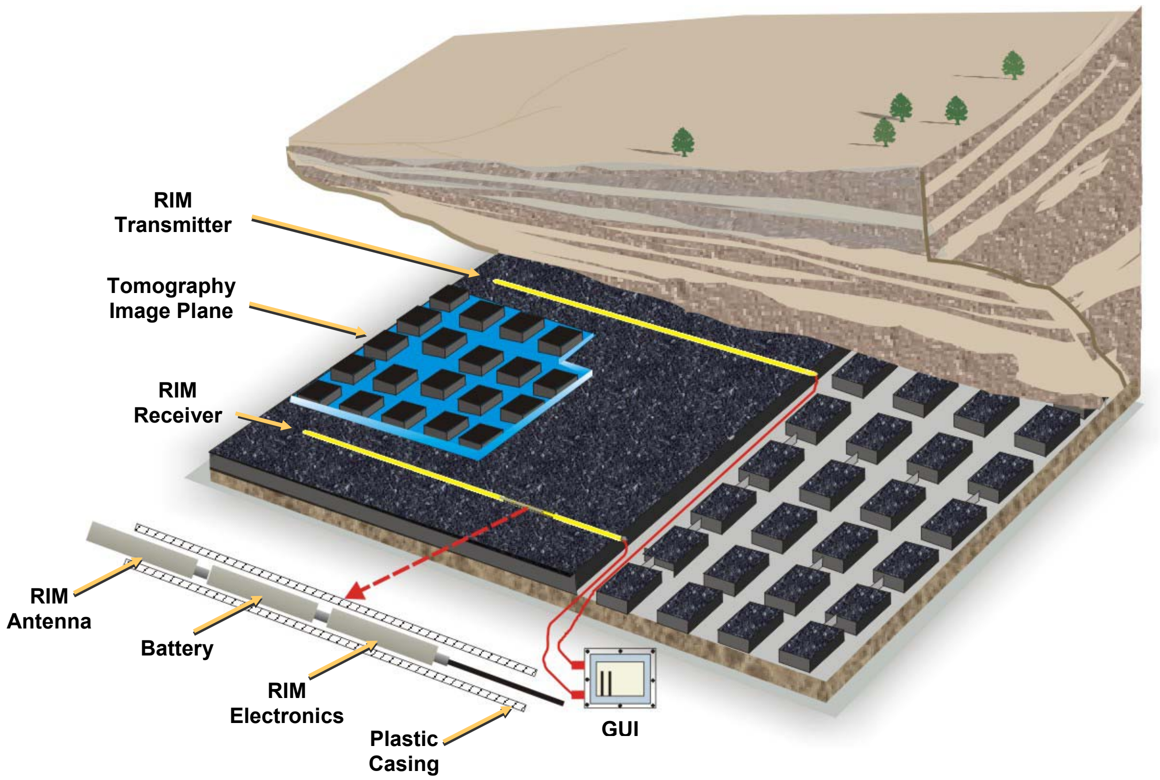

Figure 1. *Crosswell RIM imaging instrumentation of barrier pillar*

Applying Radio Imaging Method

Fortunately, there are other techniques available, such as the RIM. Introduced to the mining industry in the 1980s, there have been over 500 RIM surveys conducted in the United States, the United Kingdom, Australia, and South Africa. The technology is proven; it has created considerable value for the coal industry in identifying and imaging coal-seam anomalies. Given that a void such as an old works room is an anomaly, RIM can and has been used to locate old rooms. The key driver: the geophysical differences of coal, air, and water with respect to EM wave propagation attenuation rates, RIM can be used to identify whether or not an old room is filled with air or water. Two such surveys were conducted in 2001. The National Research Council has reported such to Congress.

The strategy for applying RIM is to conduct imaging surveys between holes as depicted in Figure 1. Inserting a radio transmitter in one hole and a receiver in another, energy in the form of EM radio waves can be sent through the coal seam. In fact, because of the geophysical differences of the coal seam and the host strata, the seam is the conduit or waveguide. It is this use of the coal seam as a waveguide that differentiates RIM from other techniques such as GPR or seismic systems.

An advanced version of RIM known as RIM IV has just been released that can now enable investigation between boreholes up to 1,800 feet apart. As part of the Mining Industry of the Future Program, the National Mining Association (NMA) and the

Department of Energy National Energy Technology Laboratory co-sponsored the advancement of RIM. Several years ago, NMA sponsored a CEO technology road-mapping workshop where imaging ahead of mining was identified as one of the top five critical technologies needing advancement to enable mining in deeper, thinner, and more complex geology. Recently demonstrated in the United States and United Kingdom, RIM IV not only achieves a greater distance of TX and RX separation, but the new system incorporates measurements of signal phase shift, in addition to existing attenuation rate. The additional investigative data (attenuation and phase shift), coupled with advanced algebraic reconstruction technique (ART) computer models, which feature full-wave inversion code (FWIC), such as the one developed by Dr. Gregory Newman of Sandia National Laboratories, three-dimensional images can now be developed providing geologists and mining engineers with greater information and intelligence about their coal seam—including the location of voids, such as old rooms. FWIC modeling was also presented to the Special Commission in testimony at the Pottsville hearing.

The key benefit of RIM IV is that with greater transmission distance in the coal bed, considerable drilling can be eliminated. In the case of vertical drilling, instead of 20-foot centers, the pattern might be extended to 1,000-foot centers. In a program to ensure a barrier pillar “Fence Line” of 2,000 feet, 90 to 95 holes could be eliminated, saving at least $250,000. The same impact is true for horizontal programs.

RIM has been used to confirm old works. Figure 2 shows an old mine map with an overlay of RIM investigation to confirm the presence of coal pillars and air and/or water voids.

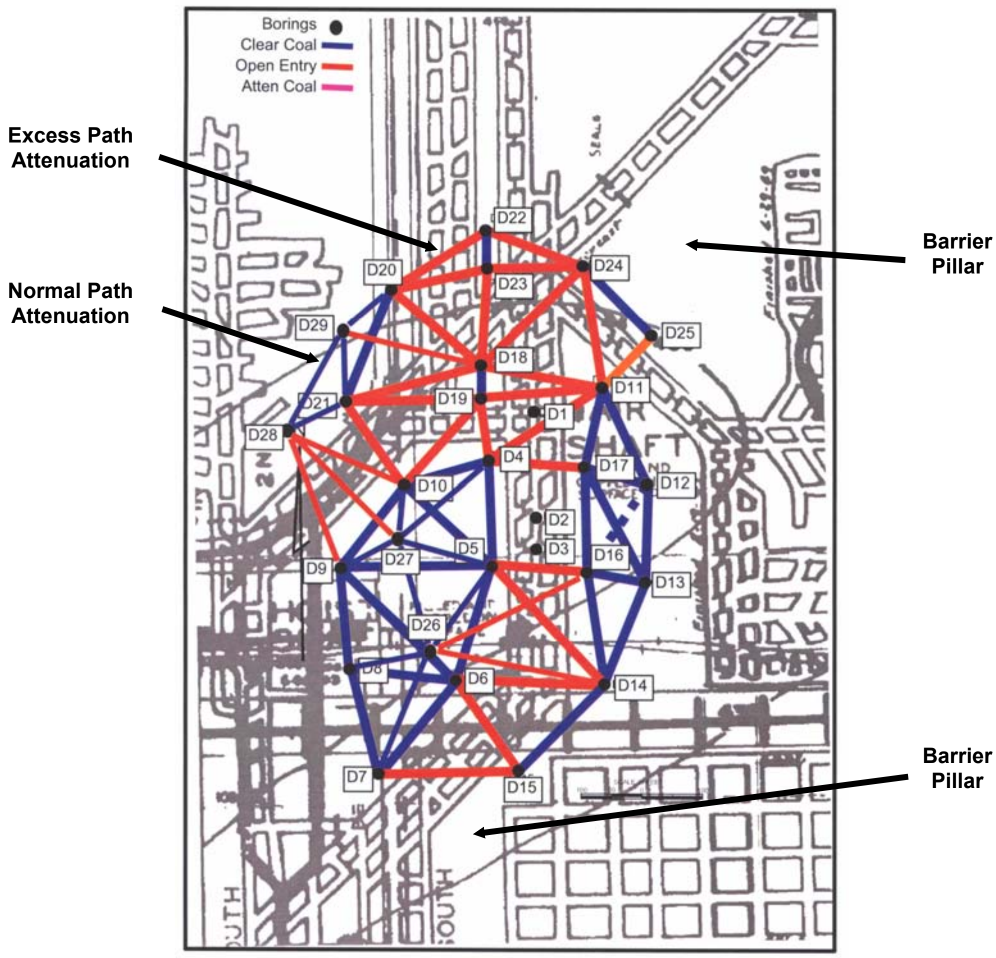

Figure 2. Plan view of abandoned mine crosswell RIM ray paths

Conclusions

As presented to the Special Pennsylvania Commission, RIM is cost effective, and a reliable system for confirming barrier pillars. It is a proven and reliable system; as confirmed by Governor's Schweiker's Special Commission, the benefit of supplemental barrier confirmation using RIM is an accepted practice.