



# Preventing roof fall fatalities during pillar recovery: A ground control success story



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## ABSTRACT

For decades, pillar recovery accounted for a quarter of all roof fall fatalities in underground coal mines. Studies showed that a miner on a pillar recovery section was at least three times more likely to be killed by a roof fall than other coal miners. Since 2007, however, there has been just one fatal roof fall on a pillar line. This paper describes the process that resulted in this historic achievement. It covers both the key research findings and the ways in which those insights, beginning in the early 2000s, were implemented in mining practice. One key finding was that safe pillar recovery requires both global and local stability. Global stability is addressed primarily through proper pillar design, and became a major focus after the 2007 Crandall Canyon mine disaster. But the most significant improvements resulted from detailed studies that showed that local stability, defined as roof control in the immediate work area, could be achieved with three interventions: (1) leaving an engineered final stump, rather than extracting the entire pillar, (2) enhancing roof bolt support, particularly in intersections, and (3) increasing the use of mobile roof supports (MRS). A final component was an emphasis on better management of pillar recovery operations. This included a focus on worker positioning, as well as on the pillar and lift sequences, MRS operations, and hazard identification. As retreat mines have incorporated these elements into their roof control plans, it has become clear that pillar recovery is not “inherently unsafe.” The paper concludes with a discussion of the challenges that remain, including the problems of rib falls and coal bursts.

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## 1. Introduction

Pillar recovery has always been an integral part of underground coal mining in the US. When room-and-pillar methods are employed, large blocks of coal in the form of pillars are initially left in place to support the weight of the overburden. Unless these pillars are subsequently recovered, the coal they contain will never be mined.

During the retreat mining process the roof above the worked-out area caves and the overburden subsides (Fig. 1). Because premature caving can cause hazardous roof falls while the miners are still present, pillar recovery has historically been less safe than other underground mining methods. A century ago, Rice found that of 317 miners that were killed by roof falls in one year in Pennsylvania, 98 perished while attempting to recover pillars, showing that “Drawing pillars is plainly most dangerous work” [1].

As noted in Fig. 1, the gob is the area where the pillars have been extracted and the roof has caved.

## 2. Demographics of pillar recovery

No official statistics are available on the prevalence of retreat mining. Indeed, collecting such data would be difficult, since many mines switch back and forth from development to retreat mining. Fortunately, through the years a number of “snapshots” have been taken of the retreat mining segment of the industry.

Kauffman, Hawkings and Thompson developed a retreat mining manual which included a survey of roof control plans from all over the US [2]. They found that out of the 4166 underground coal mines operating during the late 1970's, 1093 (26%) included pillar recovery in their roof control plans. The regions with highest rates of retreat mining plans were PA (pillar extraction included in 70% of plans), Northern WV (60%) and the Western US (56%). In the Central Appalachia coalfields, which covers Southern WV, Eastern KY, Western VA, and Northeastern TN, only 23% of the roof control plans included pillar recovery. But because there were so many mines located in Central Appalachia, a large majority (79%) of all US retreat mines were located there. Kauffman, Hawkings and Thompson made no attempt to determine the production or the number of miners at the pillar recovery mines [2]. A NIOSH study

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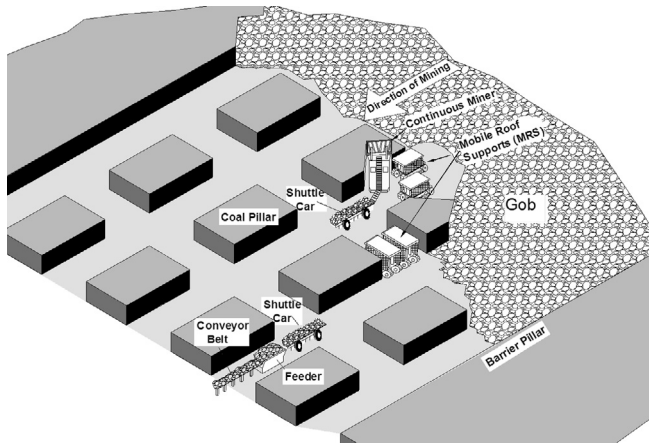


Fig. 1. Retreat phase of room-and-pillar mining showing pillar recovery.

made use of a 1993 MSHA survey of gob ventilation and bleeder systems in US underground mines [3]. The MSHA survey found that 367 non-longwall mines had gob areas, about evenly split between “active” and “inactive” gob areas. The NIOSH study linked only the mines with active gob areas to the MSHA accident and employment data base, and found that they employed 9,100 miners and produced 61.7 million tons, while the totals for all room and pillar mines were 33,100 miners and 214.3 million tons. NIOSH also found that about two-thirds of the active retreat mining was taking place in Central Appalachia, with some of the remainder coming from every other coalfield except Western KY. However, the NIOSH study significantly underestimated the total size of the retreat mining sector because it excluded the mines with inactive gobs. A mine was not counted unless it was actively extracting pillars at the moment the MSHA survey was conducted, even if it contained inactive gobs and was developing pillars for later extraction. In particular, small single-section mines in Central Appalachia were probably underrepresented.

A few years later, NIOSH surveyed MSHA roof control specialists about the pillar recovery practices in the mines they inspected [4]. The data was again linked to the MSHA accident and employment data base. This study found that in 2001, 370 retreat mines produced 108 million tons of coal, about two-thirds of the total non-longwall underground production. At this time more than 90% of the retreat mine production came from Central Appalachia, with about 9% coming from Northern West Virginia. There was essentially no pillar recovery taking place in the Midwest or in Alabama.

Pillar extraction waned rapidly in Northern Appalachia after 2001. In recent years, the total number of retreat mines anywhere outside of Central Appalachia can be counted in single digits.

While retreat mining has largely disappeared from the other coalfields, the 2003 NIOSH survey found that in Central Appalachia mines that practiced pillar extraction accounted for about 75% of the non-longwall production in the region. A 2015 survey of MSHA roof control supervisors confirmed that ratio was still valid. So while no precise data on retreat mining has been collected since 2001, data from all Central Appalachian room and pillar mines can be considered a good proxy for the pillar recovery sector of the US underground coal industry.

Fig. 2 shows that Central Appalachian room and pillar production declined slowly between 2001 and 2011, from 108 to 82 million tons. During this same period, however, productivity also declined, from 3.12 to 1.59 tons per worker hour. Therefore, the number of miners exposed to pillar recovery likely increased during this period, peaking in 2011 (Fig. 3). NIOSH estimated in 2001 that about 10% of all underground hours were engaged in pillar recovery, and this estimate was probably valid through 2011. The

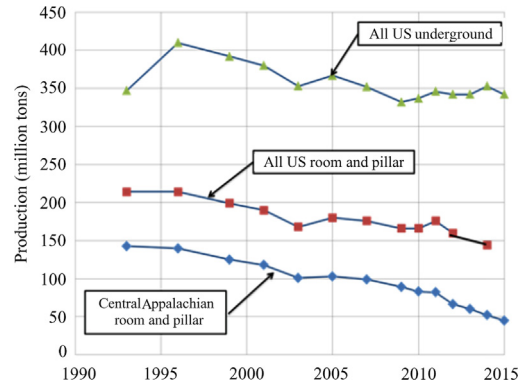


Fig. 2. Trends in US underground coal production, 1993–2015 cited in Energy Information Agency in 2015.

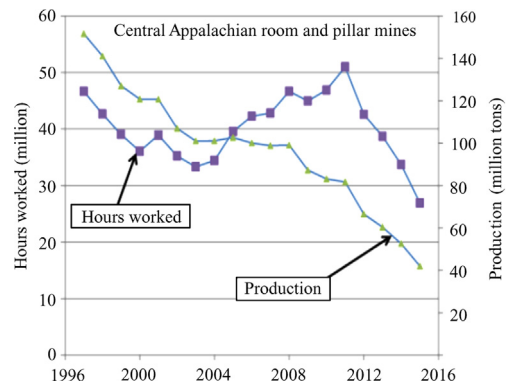


Fig. 3. Coal production and worker hours for Central Appalachian room-and-pillar mines, 1993–2015, cited in Energy Information Agency in 2015.

number of both mines and miners in Central Appalachia has greatly declined since then.

### 3. Ground fall fatalities during pillar recovery

Retreat mining has long been considered the most hazardous type of underground mining. During the first decade of the 2000's, three separate studies on the safety of pillar recovery were commissioned by the state of WV, the State of KY, and by the US Congress [5–7].

Historically, roof falls have been the most significant hazard faced by miners on pillar recovery sections. Mark found that between 1978 and 1986, out of 328 total roof fall fatalities, 67 (20%) were associated with pillar recovery [8]. For the period 1989 to 1996, Mark et al. found that out of a total of 111 roof and rib fatalities, 33 (30%) took place during pillar recovery [3]. Mark et al. estimated that a coal miner on a pillar recovery section was approximately three times more likely to be fatally injured in a roof fall than a miner on an advancing section [4].

In recent years, the number of roof falls during pillar recovery has been dramatically reduced, however. As shown in Fig. 4, there has been just one roof fall fatality in the eight years since 2007. This compares to a total of 19 in the prior decade. Since the total exposure to retreat mining has only recently fallen, it seems that a retreat miner's risk of being killed by a roof fall was reduced by a factor of 16 (for the ten-year period 1998–2007, DOE statistics show that an average of 38.44 million hours were worked each year in Central Appalachian room and pillar mines. For the eight-year period 2008–2015, the annual average was 41.44 million hours. Therefore, there was one roof fall fatality during pillar

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