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Coal bursts that occur during development: A rock mechanics enigma

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ABSTRACT

Coal bursts are typically associated with highly stressed coal. Most bursts occur during retreat mining (longwall mining or pillar recovery) in highly stressed locations like the tailgate corner of the longwall panel. Others are associated with multiple seam interactions. However, a small but significant percentage of coal bursts have occurred during development or in outby locations unaffected by active mining. Most development bursts have been relatively small, but some have been highly destructive. No theory of coal bursts can be complete if it does not account for this type of event. This paper focusses on the development mining coal burst experience in the US, putting it into the context of the entire US coal burst database. The first documented development coal burst occurred almost exactly 100 years ago during slope drivage at the Sunnyside Mine in Utah. Sunnyside subsequently had a long history of bursts, mainly during retreat mining but also during development. Several Colorado mines have also experienced multiple development bursts. Many, but by no means all, of the development bursts in these western US coalfields have been associated with known faults. In the Central Appalachian coalfields, most development bursts have occurred in multiple seam situations. In some of these cases, however, there was no retreat mining in either seam. The paper closes with some lessons from this history, with implications for preventing such events in the future.

1. Introduction: overview of coal bursts in the US

The long history of coal bursts in the US has been well-documented. Iannacchione and Zelanko analyzed the US Bureau of Mines (USBM) database of 172 bursts that had occurred between 1936 and 1993 [1]. The bursts included in the database were serious enough to warrant USBM investigations and reports, and together they resulted in 87 fatalities and 163 injuries.

Iannacchione and Zelanko reported that 24 of these events, 14% of the total, occurred during development [1]. All 24 incidents were reanalyzed for this study, and it seems they fall into three categories:

(1) events that occurred at the Mid-Continent mines, located in Colorado, which were likely gas outbursts rather than coal bursts ($n = 12$),
(2) events that occurred at several mines in Central Appalachia, which were affected by nearby goafs or multiple-seam interactions ($n = 9$),
(3) three events at the Sunnyside No. 2 and Deer Creek mines, both in Utah, that were purely development bursts.

In the US, coal mines must report to Mine Safety and Health Administration (MSHA) any "coal or rock outburst that causes withdrawal of miners or which disrupts regular mining activity for more than one hour" (Code of Federal Regulations, Title 30, Part 50.2). Between 1983 and 2017, 283 bursts were reported to MSHA. Seven of these resulted in a total of nine fatalities; two on longwalls, and seven during five pillar recovery events.

Fig. 1 shows the number of bursts reported each year to MSHA. The long-term declining trend is very pronounced. During the early 1980s, approximately 14 bursts were reported each year, but, in recent years, the number has averaged less than three. The number of development bursts has also declined, with just one reported since 2010.

Fig. 2 shows that 42% of the bursts during the 34-year period occurred on the longwall face. Another 12% affected the tailgate entry at the corner of the longwall face, and 18% occurred during retreat mining. All of these locations are subject to very high stresses, and they are directly affected by mining activity and might be considered likely locations for bursts. On the other hand, 20% of the bursts occurred during entry development, and another 8% affected pillars in the headgate, bleeder, or other outby locations.

Fig. 3 shows regional trends. In Utah, 58% of the total 149 events occurred on the longwall face, and another 17% occurred either in the longwall tailgate or during pillar recovery. Similarly, in Central

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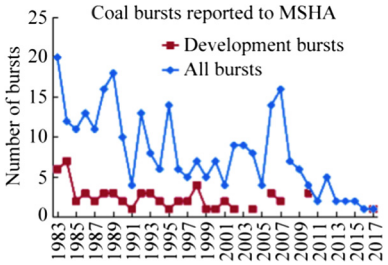

Fig. 1. Coal bursts reported to MSHA.

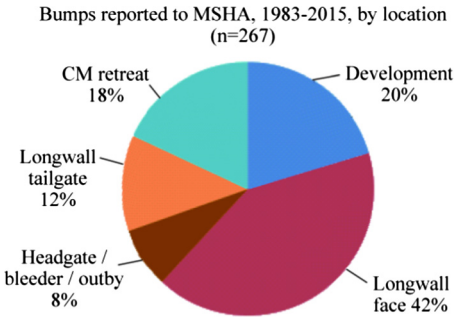

Fig. 2. Bursts reported to MSHA, 1983–2015.

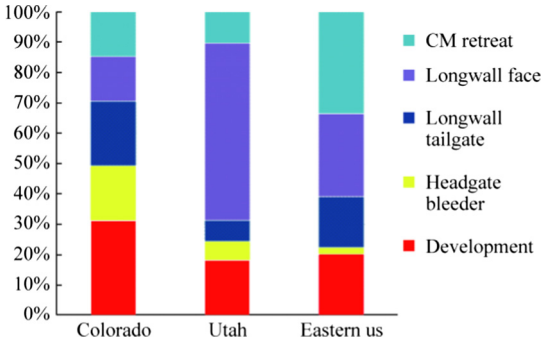

Fig. 3. Regional trends of coal bursts.

Appalachia, 78% of the 23 reported bursts occurred on the longwall face, tailgate, or pillar line. In Colorado, on the other hand, nearly half of the bursts occurred during entry development or in the headgate, bleeder, or other outby location. Although 46 of the 64 Colorado events took place in longwall mines, only nine occurred on a longwall face.

Looking in more detail at the 63 development and outby bursts, none resulted in a fatality. About half involved injuries, mainly minor ones. Only five resulted in serious bone fractures that required more than three months of lost time.

The development and outby bursts occurred at a surprisingly large number of mines. The 24 events in Colorado occurred at nine separate mines, six North Fork Valley (NFV) mines and three Mid Continent operations. A total of 32 development and outby events occurred in 13 different Utah mines. All of the western mines that reported development or outby bursts also reported bursts during retreat mining (longwall or pillar recovery). However, only three Central Appalachian mines reported development or outby bursts, and only one of those mines ever reported a burst during retreat mining.

2. Sunnyside Mine, Utah

The Sunnyside Mine is one of the best known burst-prone mines in the US. It operated in the Book Cliffs region of Utah for nearly a century, before closing in 1994. In response to the bursting that plagued its pillar recovery operations, Sunnyside pioneered longwall mining in the West in the early 1960s. Sunnyside also developed the two-entry yield pillar system, which has become the Utah standard for longwall burst control [2].

The overburden at Sunnyside was predominantly strong sandstone, with some beds more than a hundred meters thick. The immediate roof above the coal was generally poor, however, consisting of shales, sandy shales, thin laminations of sandstone and shale, and rider seams. The floor was a strong sandstone 6–15 m thick. The depth of cover at Sunnyside was severe even in the early days, with the 600 m cover line just 800 m from the coal outcrop due to the cliff-forming sandstones [3]. Numerous faults are present, most prominently the Sunnyside fault system which parallels the outcrop (Fig. 4).

In the early 1900s, bursts were already common in pillar workings under heavy cover at Sunnyside and at other mines within the same region [4]. Most of the really severe events were associated with the main Sunnyside fault [3]. The first significant encounter at the mine with development bursts occurred in 1918. In that instance, bursting started soon after two slopes penetrated a fault having a 5.5 m displacement. As the slopes were driven still further down the pitch, the face would blow out to a depth of 2 m, filling the entry with pea-sized pieces of coal. No further disturbances were noted after a second fault was crossed.

In the early 1940s, slope and entry headings in a virgin development burst violently, although the nearest pillar workings were 450–750 m away. They were of such magnitude as to break the top, knock out timber support, and cause roof falls, some of which were very extensive. Cover over these development workings ranged from 230 to 600 m [3].

In January of 1957, a series of events caused great damage to the main slope area near the fault. A heavily bolted section of roof in the track slope settled on the bolts throughout 150 m of track entry, and the railroad on the same slope was heaved and thrown out of line for a distance of 400 m. This same area had been damaged in bursts in 1944 and 1952.

In December of 1957, a pillar in the same area burst again, filling the manway with rock for a distance of 70 m. The entry had caved previously, and the cave had been used as fill and graded over, so the event was actually rock burst rather than a coal failure (Fig. 5). The tremor was felt at the Sunnyside Town site and was

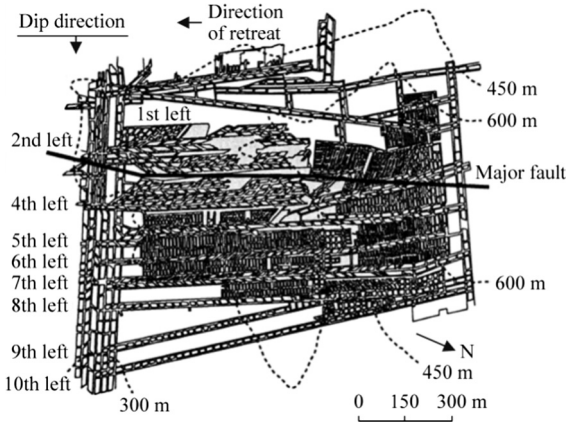

Fig. 4. A portion of the Sunnyside Mine that was mined in the 1950s, showing the Sunnyside Fault (labeled "Major fault" on the right) [2].

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